

VOLUME VI. }
NUMBER 10. }

[COPYRIGHT, 1889.]

OCTOBER, 1889.

Annual Subscriptions
to Institutions \$5.00.
Single Copies - 50 cts.

TRANSACTIONS
OF THE
AMERICAN INSTITUTE
OF
ELECTRICAL ENGINEERS.

SPECIAL MEETING, JUNE 25TH, 1889.

SUBJECT:

Some Recent Electrical Work on the Elevated Railroads.

By LEO DAFT.

SPECIAL MEETING, SEPTEMBER 10TH, 1889.

SUBJECT:

Alternating Current Motors : The Evolution of a New Type.

By LIEUTENANT F. JARVIS PATTEN.

NEW YORK CITY:

PUBLISHED BY THE INSTITUTE, UNDER THE SUPERVISION OF
THE EDITING COMMITTEE.

R. W. POPE, *Secretary*.

TEMPLE COURT, 5 BEEKMAN STREET.

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SOME RECENT ELECTRICAL WORK ON THE ELEVATED RAILROADS AND ITS BEARING ON THE RAPID TRANSIT PROBLEM.

BY LEO DAFT.

It is particularly noticeable that all who have, so far, considered the question of rapid transit for the city of New York, have assumed that it is so deficient in these facilities that the question was of the most immediate and vital importance, and, while I do not for a moment wish to underestimate the urgency of the demand to meet the rapid growth which has already almost overtaxed the elevated system, we should not lose sight of the fact that New York has even to-day, all things considered, a better rapid transit system than any other city in the world. In evidence of this it is only necessary to cite the facts that one may enter a well-appointed car at the Battery, and, traveling through the best atmosphere of the city, be carried with remarkable smoothness to Fifty-ninth street in 26 minutes, or at the average speed of 12 miles per hour including stops, and in about this manner, the elevated system contrives to carry one-half million passengers per diem for a lower rate of fare than is done in any other city for similar accommodations, and with a smaller proportion of accidents than may be found on any steam road in the world making an equal number of stops per one hundred miles run. On a recent holiday, namely, April 30th last, 835,721 passengers were carried on this much abused system without noticeable detention or accident—but New York wants more, and in view of the rapidly growing traffic which has already almost exceeded the ability of the system, it must be admitted that the demand is a pressing one, as this one half million will grow to one million in a short time, and it is exceeding improbable that

any steam motor can be devised to permit of this increase, at least on the present structures, without subjecting them to quickly destructive strains. With steam, therefore, the only avenue open for increasing the passenger capacity, namely the use of longer trains, is obviously out of the question, since it is a notorious fact that the present motors are taxed to their utmost.

To the mind of the mechanical engineer, having in view the ordinary coefficients of tractive ability, there is no remedy for this, but I think I shall be able to produce at least some little evidence that, owing to certain effects which have not yet been satisfactorily explained, an electric motor may be made capable of solving the problem at least so far as the ultimate strength of the present elevated structure will permit, inasmuch as the effects alluded to certainly do increase the tractive ability beyond that obtained by the use of any coefficients which may be found in the works of that eminent authority, D. K. Clark, or still later in the excellent treatise on the "Economic Theory of Railroad Location," by A. M. Wellington.

That these coefficients are not absolutely trustworthy is evident not only in the hesitancy with which they are treated by these authors, but also from the fact that varying coefficients are to be found in use by practical men, where the conditions do not differ in any appreciable degree. This is noticeable to the extent of nearly twenty per cent—*vide* D. K. Clark and A. M. Wellington. I will not, therefore, make pretense to great precision on this point, as the matter is one yet under investigation, but to quote an extreme case I trust I may be pardoned for going back so far as the year 1882 to the first series of experiments in which this increased tractive capacity was observed and carried to its apparent maximum.

During a series of experiments with small motors, made at the works of the Daft Company, at Greenville, N. J., in the year above quoted, I constructed an adjustable incline upon which a small motor was caused to ascend with a gradually increasing gradient until the extraordinary angle of 2,900 feet per mile, or 54.9 per cent., was reached. Up to this point the motor, weighing 450 lbs., plus one man, weighing 150 lbs., total 600 lbs., was readily started from a position of absolute rest at the bottom, and ascended the gradient, being occasionally stopped midway and started again with perfect ease. When this final gradient was reached, however, the ascension was less easy and certain, though

it was accomplished several times, but an attempt to exceed it resulting in failure this was regarded as the maximum under those circumstances.

Now let us for a moment consider what this actually indicated. A motor having a total weight of 600 lbs. will have a rolling resistance certainly equal to 10 lbs. per ton, making 2.25 lbs. for this item; at 54.9 per cent. the grade resistance will be 320.4, making a total of 331.65 lbs., or 55.27 per cent. of the total weight, considerably more than double the ultimate working limit of adhesion under the most favorable condition cited by Wellington in the work already quoted; but as these conditions, namely, a perfectly dry rail with drivers absolutely free from any lubricant, are so rarely found in practice as to be scarcely worth taking into account in every day work, it may fairly be considered as equal to three times the ultimate effort usually developed before slipping occurs.

A prominent engineer in dismissing the idea of increased traction due to the passage of a current between the adhesive surfaces, falls into the error of assuming that the effect would be precisely the reverse of that which has been observed, and in support of his argument cites the case of the lessened friction between the metallic points and the cylinder of chalk noted in a well-known instrument. I need hardly, however, call the attention of this audience to the entire absence of any proper analogy between these two cases. That the motor should not have ascended this gradient I am well aware—indeed, out of the commonest respect for such authorities as Messrs. Clark and Wellington, it ought to have stopped at the bottom of the gradient meekly rotating its wheels, but I was confronted by the indisputable fact that it did go up, and did it every day with perfect regularity for a number of days, before many gentlemen, among whom were mechanical engineers who could not account for that state of thing at all—and frankly, neither could I, but as a cold fact it outweighed all the arguments in the universe. In illustration of my own doubts on the subject I may mention a little instance that occurred at that time; I had written to a mechanical engineer of my acquaintance stating the facts, and received in reply such an astonishing array of diagrams and mathematical proofs that this could not be done that I actually went into the yard and had the motor perform the feat several times before I felt strong enough to write my friend in a half apologetic way, acknowledg-

ing the soundness of his views, but being compelled to reiterate the statement that the thing was being done just as I stated.

But seriously speaking, the significance of this test can scarcely be overestimated, showing as it undoubtedly did, the possibilities of working under conditions which have been hitherto considered impracticable.

Now I do not for a moment pretend to assert that either dynamic or static adhesion may be increased to this extent by a large locomotive under the conditions of ordinary practice, as I am fully aware from subsequent experiments that the observed effect in this instance was due to a very large current of low potential passing through the very small contact-areas presented by wheels only one foot in diameter, impinging upon a light sixteen-pound rail, the effect is, however, undoubtedly obtainable to the extent of at least thirty per cent., under the ordinary conditions of railroad practice, since I have observed it many times with a dynamometer by causing the current to pass from wheel to rail in one series of measurements and through a cable connected with the motor in another series, and in this way results as high as thirty-five per cent. increase have been many times noted. In addition to this it is more than probable that the tractive efficiency of electric locomotives is higher than that of ordinary steam locomotives for mechanical reasons, and in this connection I cannot do better than quote Professor John E. Sweet, in a recent article in the *American Machinist*, since it is put in a direct, clear, and simple manner. But as Professor Sweet declines to admit the increase to be due to electrical action, I quote him simply in evidence of one of the mechanical advantages of the electric motor:

TRACTION EFFICIENCY OF ELECTRIC LOCOMOTIVES.

Reference has been made to the fact that the electric locomotive will draw a considerably heavier load than the steam locomotive of the same weight, and the suggestion advanced that it is due to some electric condition of the rails and wheels, while I believe it has been clearly shown that certain things slide one upon the other much more freely when a current of electricity is passing from one to the other than when not. I do not know whether, in the case of the Ninth avenue cars, electricity passes from the wheels to the track, but if it does, the result is quite the reverse from the action assumed in the case of the locomotive wheels, and it does not seem at all necessary to refer the matter to any electrical or magnetic theory, as the mechanical conditions alone are such as to explain the apparent inconsistency, and in this way: The power of the electric motor is constant and the steam intermittent. If the steam locomotive has but a single cylinder, and the power required to draw the train be 700 lbs. the force exerted by the piston would be zero when the crank was at the dead center, and 1,100 lbs. at the maximum; so that while the electric motor doing the same

work would exert only 700 lbs. toward slipping the wheels, the steam locomotive with one cylinder would at times exert a force of 1,100 lbs. This assumption does not take into account the varying steam pressure, nor the angularity of the connecting rod, which in certain positions would make it more, nor the weight of the reciprocating parts and the inertia of the drivers, which would make it less, though, as slipping takes place in starting the train, the inertia would have but little influence.

It is true that the steam locomotives are not single cylindered, and at first sight it would seem that that makes a vast difference, and that with two cylinders the impulse is almost constant; but even assuming the pressure to be constant throughout the stroke, as was assumed with the single cylinder, the rotary effect of the two cylinders is not constant, and (unless I am badly mixed in my diagram) with a mean 1,400 lbs., or double the mean of the single cylinder, there will be a minimum of 1,100 lbs., and a maximum of 1,571 lbs. This variation, together with the varying steam pressure on the piston, it would seem, is sufficient to account for the extra efficiency of the electric motor. If I am correct in my assumption that the limit in both cases is the slipping of the drivers,

I have dwelt longer on this branch of the subject than it might seem to warrant for the reason that an eminent authority, in a paper read some three or four years ago, emphatically declined to admit this line of argument or the existence of this effect, and, in strongly advocating a multiple motor system, declared that increased weight was the only possible means of increasing the tractive ability of the motors and that to propose any other plan was simply to shut our eyes to plain mechanical and engineering truths. I am pleased to observe that in a later paper the truth of the effects which I had discovered and strenuously insisted upon early in 1883, have been acknowledged by the same authority.

Referring to the plan of multiple motors where it was proposed to use one or two machines on each car, while there can be no question that the advantages are theoretically very marked in some directions, I think the multiplication of motive parts, necessarily much smaller and more liable to derangement than those on one machine of equivalent power, together with enormously increased first cost, and cost of attendance and repairs, present practical disadvantages from which any railroad manager would naturally shrink; and, notwithstanding the able manner in which this plan has been presented and its obvious theoretical solution of a much vexed problem, I do not see any reason for changing my original plan; on the contrary, exhaustive experiments recently conducted lead me to the conclusion that the problem may be readily solved in another way.

Lest any misunderstanding should exist as to the object of this

series of tests, permit me here to remind you that this motor was not expected to solve the problem by towing longer trains at higher speeds than are at present attained. It was simply for the purpose of proving that a machine weighing little more than one half the present motors would equal, or nearly equal, their performance in that respect, and, while it must be admitted that in the matter of acceleration on the heavier gradients the steam motors still show somewhat greater ability, the result of the test indisputably proves that, with motors of the same weight as those now employed, at least six car trains on the Ninth Avenue, and seven to eight car trains on the Sixth Avenue, may be propelled at a considerably higher average speed than at present, and when the absence of reciprocating parts is taken into account, the advantage on the side of the electric motor, in lessening the destructive strain on the structure, will form an important factor in the economy of operation. That the absence of this destructive strain is no idle dream of the mechanical engineer has been fully realized by many competent observers of the electric trains, and it has been a subject of general remark that the noise of the electric train is merely that inseparable from the rolling of wheels over the track, the motor itself making no more noise than one of the cars in motion.

I refer to these points particularly because so many disappointments have been experienced by the public, who seem to expect the electrical genie to wave his magic wand over the earth and cause all mechanical difficulties heretofore experienced to vanish in a moment, hence it is pleasant to be able to refer to the actual accomplishment of some of the most desirable advances in municipal rapid transit.

But the principal object is to show without fear or favor that it is now possible to run, and compete with steam on the Ninth Avenue railroad; and, of course, any of the others with a certain concrete economy based upon a series of tests made under circumstances to the last degree prejudicial for an economical showing and without taking into account the great gains which would inevitably result from the use of a large central station, with dynamos of the highest efficiency, and with the obvious advantage resulting from the operation of a number of motive units under varying loads from a central station or dwelling upon such abstract economies as freedom from cinders, dropping water, smoke and noise.

Before proceeding to a review of the actual accomplishment, allow me to briefly describe the motive machine in question. The motor, named "Ben Franklin," consists of a frame having two driving wheels coupled by discs outside the bearings, with two cast-steel cut split gears mounted on the back axle and an electric motor pivoted on pedestals at the rear of the cab and supported on similar pedestals with a screw adjustment for raising the whole machine to remove the armature, and wrought steel pinions in nearly vertical engagement with the gears.

It is evident that a considerable degree of resilience is not permissible with such an arrangement, but a sufficient amount to prevent excessive hardness in working is obtained by placing alternating plates of rubber and iron in the pedestals, above and below the bearings. A similar arrangement at the driver-bearings cushions the machine without interfering with the mesh to an appreciable degree, in fact what little wear has so far been observed between pinions and gears shows remarkable uniformity of engagement.

Before the motor was placed in the cab it was deemed advisable to make a few Prony brake tests of its ultimate ability; it was therefore placed in the central station at 15th street and a series of tests made, resulting in the development of 128 horse power. A few higher readings than this were apparently taken but as some little doubt is felt as to the accuracy of the observation, those were rejected and the above accepted as the ultimate reading.

The piece of track upon which the experiments have been conducted is eminently adapted for testing the tractive ability of a motor for this purpose, since there is only one piece of level track, 2200 feet in length, the rest, embracing a distance of 1.846 miles, consisting of gradients varying between 11.3 and 98.7 feet per mile, and in one instance, namely, at 30th street, the start is made only a few feet from the bottom of a 98.7 foot gradient, thus testing the tractive capacity of the motor to the utmost.

In October last, experiments with this machine were begun on this piece of track, which, through the courtesy of Col. Hain, was placed at my disposal from 9 o'clock at night until 4 o'clock the next morning, and the first experiment consisted in taking a light load of one or two cars over the road to test the conductor and switch connections. This was gradually increased night after night, until one of eight Ninth Avenue cars, each weighing

12 tons, was towed over the entire road, going up the 98.7 feet grade at a speed of $7\frac{1}{4}$ miles per hour, and making the entire distance in 7', 35", or at an average speed of 14.6 miles an hour. Although a drizzling rain prevailed and the rails were moist, there was an entire absence of slipping.

I regret that at the time of this experiment we were not using the dynamometer, but taking the ordinary coefficient of rolling friction for a light train of this kind, namely, .004, and assuming the grade resistance to be at the same rate per cent. of the total weight of the train as the rate per cent. of the grade, and the rate per cent. of the grade being 1.86, we get the following, $\frac{1.86 \times 4781 \times 660}{321600}$ 95.8 h. p. to which should be added at least 15 per cent. for friction and a so-called "head resistance" of the motor, equalling 14.37, or a total of 110.17 h. p. at 15th street.

The maximum velocity obtained by that train on the level in passing 23d street was 24 feet per second, or 16.36 miles per hour.

These tests were continued for several weeks at intervals of two or three nights, during which time a great number of experiments were tried as to the ability of the motor to make the switches, start on gradients, etc., and I am able to state, as a simple matter of record, that, though the tests were of the most exacting character, absolutely the only repairs or delay during all this time and subsequent tests were two, once when a spool had to be removed from developing a contact, which caused a delay of one night, and the other time when a moving axle wore a hole through the insulation of an end spool and caused a delay of fifteen minutes. With these two exceptions the motor has been ready to run at any moment during the whole time, in spite of the roughest treatment and being left on the track exposed to the weather for months past.

I think I am entitled to say that these results, which were of course carefully watched by the Manhattan railway officials, led to our obtaining permission to run in the day time between steam trains—a permission which you may be sure would not have been granted on a road which has a world-wide reputation for its almost military discipline and precision of management—if the motor had not earned the right to some confidence. On the 28th day of January, 1889, we began running between the hours of 11 and 2 in the day time, which was continued with a three-car and occasionally a four-car train, running express until the 12th day of February, when we were requested to take a train of flat cars

loaded with iron to the weight of an average four-car train with seventy-five to one hundred passengers, in lieu of the light train formerly employed. With this train, weighing in all 70 tons, I made several trips over the road between the ordinary steam trains, but finding the brakes hardly trustworthy enough for such critical work with trains only three minutes from us on either side, it was decided to discontinue this service and a four-car Sixth avenue train was substituted. With this train several trips were made, but in consequence of the absence of air brakes it was not considered advisable to proceed with the ordinary "stop run," and the remainder of the work was done at night. But I may say that during this period of 30 days with one exception above noted, not the slightest detention was caused to the regular trains, as we were always able to switch onto the track, make our trip and get back onto the switch at 50th street without interfering with the steam trains in the least.

A number of experiments made about this time show that the mean speed, with a three-car empty train, running express on the up-town track, was about 23 miles per hour, though on the level, the ability of the motor with a similar train is nearly 28 miles per hour. This is by no means the limit of speed which the motor is capable of attaining, for as will be seen by reference to diagram No. 1, the work of acceleration was still in progress when the gradient at 24th street was encountered, hence it seems perfectly fair to assume that, even with that 40 ton train, the maximum level speed is not shown. With a lighter load the speed would undoubtedly be much greater, but for prudential reasons it was not deemed well to push this matter of speed to its extreme limit, especially in view of the fact that the machine was not designed for a speed of over 25 miles per hour, and any derangement resulting from excessive peripheral armature speed might have prevented my ability to present a clean record to-night.

To any one traveling on a structure similar to the Ninth avenue elevated road a speed of 28 miles per hour, particularly at night, and at an altitude of thirty feet, seems to be sufficient for all practical purposes, and I must confess that in driving the motor at that speed under those conditions, I was conscious of a marked absence of any desire to greatly increase it; neither does it seem to be necessary that greater speeds than thirty miles per hour should be attained in the city limits (by express trains) to meet all the proper requirements of rapid transit, and when the great

power which experiment shows to be required for the accelerative effort between the frequent stations, and with the comparatively heavy trains on the Sixth and Third avenues are taken into account, it is extremely improbable if this speed will ever be exceeded between stations on these structures.

Referring to the methods adopted in making the measurements which are plotted on the diagrams, it should be noted that wherever any doubt existed as to the effect of the personal equation in the observations, changes were made in the observers, and the experiments repeated, so as to leave scarcely a possibility of any material error, and in order that the always objectionable average statement should not contribute to confuse the result, the diagrams were taken from a number of similar ones which, after careful examination were found to most fairly represent the mean effects. They are, therefore, within the limits of error in observation, the exact results of actual performance.

In order to measure the speeds with sufficient accuracy for all practical purposes, I divided the track into nineteen sections of 500 feet, each section being provided with a thin copper plate attached to the guard rail at the side of the track, and connected with the copper rod or insulated side of the conductive system. This plate was made as short as possible to insure a complete contact without occupying an appreciable interval. A copper brush attached to the motor in such a manner as to travel on the top of the guard rail was connected with one terminal of a chronograph of the well-known type, which we made for this purpose, consisting of a paper covered cylinder rotated at a uniform speed by clock work, and a stylus actuated by an electro-magnet so as to penetrate the paper at every closure of circuit. This instrument was carefully tested and the results verified by experiments before the readings were accepted. The indicator cards were taken at the central station by Mr. Idell and his assistants, after a careful comparison of watches so as to insure synchronism in observing the effects of acceleration and gradients. The dynamometer used was a very fine specimen of the liquid type owned by the Manhattan railway, and made by Mr. Shaw, of Philadelphia, and after careful calibration by Mr. Shaw and Mr. Idell, was found to be accurate within an inappreciable amount. The dynamometric readings I have omitted from these observations for the reason that they were found to throw so much light upon the ordinarily accepted coefficients of train resistance under many of

the conditions which the text-books have not yet considered, and especially the formulæ relating to the subject of acceleration, that time would not permit a thorough digest of the results, hence it was deemed better to leave this part of the subject for later consideration, and I trust you will shortly hear from Mr. Idell on this subject, in his usually able and thorough manner.

Referring to the diagram No. 1, representing the run of a two-car express train, having a total weight of 40 tons, it will be seen that the initial indicator card is exceedingly high as compared with the apparent effort required. The reason for this is that our plan in taking the cards was to make the first one at the instant of closing the circuit, thus giving a card due to the simple dead resistance of the motor which, with a ratio of peripheral velocities necessary for this work and a speed of 30 miles per hour, would necessarily be low and occupy at least a few seconds in developing an economic working resistance, unless a somewhat complicated arrangement was resorted to. But this point will be later referred to.

Following the speed line it will be seen, as might be expected, since we see that the accelerative effort is rapidly diminishing towards the foot of the gradient, that the indicator cards become a minimum at the maximum velocity of the train, but quickly rise beyond 27th street, where the gradient is 98.6 feet per mile. The effect, however, of acquired momentum is here very evident, since neither the indicator cards nor the declining velocity are at all proportionate to the resistance imposed by the gradient, and the speed of the train varies but little from this point to 46th street, being only slightly increased on the down grade between 34th and 42d streets, due to a change in the combination for the purpose of checking what would otherwise have been too great speed for safety. The dips in the indicator line between 36th and 37th streets is occasioned by the cards having been taken at the instant of the change in combination; at 46th street the decrease in speed is the result of encountering the gradient, 76.1 feet per mile, and between 48th and 49th streets the circuit was opened for the stop at 50th street, when, as will be seen, the indicator line quickly drops to the friction card only. This run of 1.846 miles was made in 4 minutes and 51½ seconds, as recorded by the chronograph. This is at the mean speed of 22.86 per hour, with a maximum of 28.4 miles per hour indicated on the up grade be-

tween 44th and 46th streets. The speed in passing 23d street, the end of the level stretch, was 29 miles per hour.

The mean power exerted at the central station for propulsion during this trip was 103 horse power, which will compare not unfavorably with steam practice.

Turning to diagram No. 2, representing a four-car express train, having a total weight of 70 tons, or about the average weight of a four-car loaded Ninth avenue train, we are confronted with the curious fact that the initial indicator card is lower than that shown with the two-car train, but a careful examination of the two diagrams will show that the card was taken a few seconds after the stop and not, as in the case of the two car train, at the instant of closing the circuit. The effect, therefore, of the rapid development of working resistance is very clearly shown and is a most important factor in considering the high initial cards, since they are of only an instant's duration and hence comparatively unimportant in their effect upon the total power required to run a considerable number of trains at one time. In this run the characteristics of the two-car run are very nearly reproduced, though it is particularly noticeable that the indicator line does not show so large an increase as one might, at first thought, expect from doubling a number of cars, but this is accounted for by the greater ratio which the friction and load of the motor presents to the two-car train.

The total time of the trip with this train, consisting of 4 Sixth avenue cars, each weighing 15 tons, plus the motor, weighing 10 tons, was six minutes and six seconds, with a mean speed of 18.15 miles per hour, and with a maximum speed of 25.24 miles per hour between 42d and 43d streets, which is, however, almost equal between 24th and 25th streets, when, as above noted, acceleration was still in progress. The mean power exerted at the central station on this run was 129.3, resulting from 91 ordinate readings. This result is almost exactly the same as the running time of the express steam trains of equal weights over the same distance and may be repeated at any time.

Comparing the two former with diagram No. 3, representing a four car "stop run," several of which were made chiefly for the purpose of demonstrating the ability of so light a motor to stop at the foot of a gradient of 98.7 feet per mile, as at 30th street, with a train of 70 tons; and ascend the gradient from a position of absolute rest with ease. These "stop-runs" with this train,

were made many times without encountering any difficulty whatever, and at no time during the whole tests has the motor shown indications of overload. That the four-car "stop-runs" were not made in schedule time will be seen by the diagram, but a careful inspection of the same will show the exceedingly prejudicial effect of the absence of an efficient brake system, compelling the opening of the circuit two or three blocks before the station is reached, in order to ensure a proper stop at the platform. This is graphically shown on the indicator lines of the diagram where the circuit is seen to be open at 19th street, for the stop at 23rd, thus considerably lowering the speed, and of course stopping the rapid acceleration shown on the speed line at the third chronograph station. This disadvantage was so marked that I do not present the four-car "stop-run" as evidence of anything but the ability of the motor heavily loaded to ascend the gradients under the exacting conditions of an exceedingly difficult piece of track.

That there is not a marked difference between the ten ton motor and the eighteen ton locomotive in the initial effort on the level, may be seen by comparing a run observed by a Manhattan railroad official, on March 9th, last, with a steam motor and three-car train with 75 passengers, or a total of about $57\frac{1}{2}$ tons; we see that while the steam motor required one minute and thirty-nine seconds to make the distance from 14th to 23d streets, the electric motor in diagram No. 3, accomplished the trip, with a train weighing 14 tons more, in one minute and fifty seconds, or only eleven seconds added for the increased 14 tons. Surely not a discouraging exhibit, considering the fact that while the absence of powerful brakes compelled the opening of the circuit at 19th street, the throttle of the steam motor was probably open up to 22d street, although on this point I have no direct evidence—but that is the usual practice.

Before dismissing this diagram, I will again remark that while the mean speed was not equal to the ordinary schedule of the Ninth avenue road, it is nearly equal to that of the Third avenue, with 22 ton motors and 80 ton trains. In considering the apparent mean expenditure of power at the central station, it should be borne in mind that the efforts exerted by these motors on such rapidly varying gradients, and over such short distances on the elevated railroads, are not by any means represented by the ordinary coefficients of train resistance and effects of gravity, as it has been before pointed out very clearly by others



25-30 miles per hour



Chronograph Stations 500 feet apart.

Car Trolly

Diagram



25-30 miles per hour



Chronograph Stations 500 feet apart.

Car Trolly

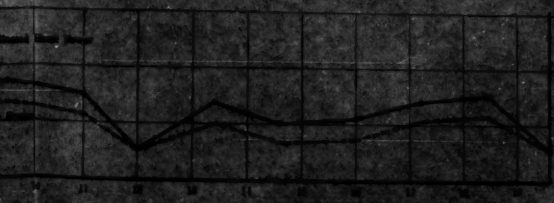
Diagram

CHRONOMETER ELECTRICALLY WOUND FOR THE



Time 4 min. 4 sec.

DIAGRAM 1.



Time 4 min. 14 sec.

Diagram 2.

that, while the up grades always exert their full effect, the advantage generally obtained from down grades on long runs by acquired momentum, is here nearly always lost by the position of the gradients with reference to the stops. It has been shown by Messrs. Sinclair and Campbell that on the Third avenue road with the 80 ton trains and 22 ton motors, 170 horse power is not infrequently exerted, hence to consider this problem merely by the ordinary coefficients of rolling friction and gravity resistance would, and does frequently, lead to very serious errors in computing the amount of power actually used, on short railroads, with frequent stops.

However it is not my purpose to enter into the niceties of train resistance, since the best authorities differ widely on these points, and theoretical economics form no part of the present subject. But as I think I am presenting to you for the first time a critical examination of actual competition with steam motors on steam roads, in the work of towing entire trains, I trust you will not fail to recognize that electricity is at last measured and weighed against its most formidable opponent in railway practice.

For many years the electric motor struggled hard to prove its ability to compete with even the most costly competitors, namely, manual labor, and even here the introduction of the dynamo machine was necessary to achieve the victory; then quickly followed the long competitive battle with horses, in which it is evident the equine has been signally defeated, and to wrest a victory from the steam locomotive in its own domain is quite another matter, but I think you will agree with me, that proof of a large economy in the vital item of fuel, under decidedly adverse circumstances, may be so construed without dangerous optimism; and the result of all these tests has seemed to prove that the measurements might be laid bare without in the least shaking the confidence of competent judges in the ability of the electric motor to replace steam for service, at least as severe as that of the elevated railroad systems; and in amplification of the results obtained, we have here a diagram (No. 4) graphically representing the present service of the Ninth avenue elevated road, where the positions and number of trains for all hours of the day are plotted, and the actual horse-power required, as shown by the indicator cards.

No. 1:

10 three-car trains to be run under six-minute headway between 59th street and South Ferry.

Train No.	Location.	H. P. Required.
10	Starting at 59th street.....	200
9	Up grade to 34th street.....	150
8	Running on level ..	130
7	" " ..	130
6	Starting at Battery place.....	190
5	" Rector street.....	190
4	Running on level.....	130
3	" " ..	130
2	Down grade to 42nd street.....	—
1	On switch at 59th street.....	—
		1250
Add 10% for contingencies.....		125

Total..... 1375

ESTIMATED AMOUNT OF POWER REQUIRED TO EQUIP, ELECTRICALLY THE NINTH AVENUE DIVISION OF THE MANHATTAN ELEVATED RAILWAY.

10 four-car trains to be run under six-minute headway between 59th street and South Ferry.

Train No.	Location.	H. P. Required.
10	Starting at 59th street.....	200
9	Up 52 feet grade to 34th street.....	200
8	Running on level.....	150
7	" " ..	150
6	Starting at Battery place	200
5	" Rector street.....	200
4	Running on level.....	150
3	" " ..	150
2	Down grade (52 feet) to 42d street.....	—
1	" " into switch 59th street.....	—
		1400
Add 10% for contingencies.....		140

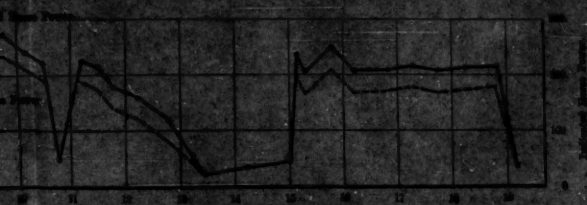
Total 1540

15 four-car trains to be run under four-minute headway between 59th street and South Ferry.

Location of trains when train No. 15 has been under way two minutes.

This gives larger results than when train No. 15 is starting from 59th street.

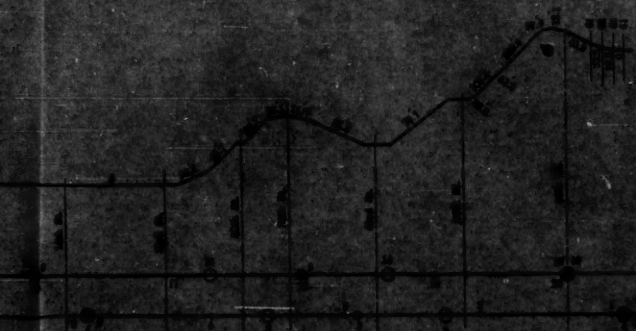
Train No.	Location.	H. P. Required.
15	Down 105 feet grade to 50th street.....	—
14	Up 52 feet grade to 34th street	200
13	Running on level	150
12	Starting at Christopher street.....	200
11	Running on level.....	150
10	Starting at Cortlandt street.....	200
9	" South Ferry.....	200



Car Traction - Way Run.

Time 20 min. 55.4 sec.

GRAPH 5.



1000 Roadway.

GRAPH 4.

ELEVATED RAILROADS—Lino Park, June 2nd, 1904.

RECENT ELECTRICAL WORK

Train No.	Location.	H. P. Required.
8	Battery place.....	200
7	Barclay street.....	200
6	Running on level.....	150
5	".....	150
4	Up grade from 23d street to 30th street.....	200
3	Down grade to 42d street.....	—
2	Up 105 feet grade to 59th street.....	250
1	On switch.....	—
		2250
	Add 10% for contingencies.....	225
	Total.....	2475

20 four-car trains to be run under three minute headway between 59th street and South Ferry.

Advancing trains one minute from start.

Train No.	Location.	H. P. Required.
20	Down grade to 50th street.....	—
19	" " 42d street.....	—
18	" " 30th street.....	—
17	Running on level.....	150
16	" ".....	150
15	" ".....	150
14	Starting at Franklin street.....	200
13	" Barclay street.....	200
12	" Battery place.....	200
11	Running on level.....	150
10	Starting at Rector street.....	200
9	Running on level.....	150
8	Starting at Warren street.....	200
7	Running on level.....	150
6	" ".....	150
5	" ".....	150
4	Starting at 30th street.....	250
3	" 42d street.....	200
2	Up grade to 59th street.....	250
1	On switch at 59th street.....	—
		2870
	Add 10% for contingencies.....	287
	Total.....	3157

RESUME.

And to obtain the average for the day.

Train No.	Cars on Train.	Headway.	Time		Time in Service.		H. P.	H. P. hours.
			A. M.	A. M.	hrs.	min.		
10	4	6 minutes.	5.09	to 6.03	0	54	1540	800
20	4	4 "	6.03	to 6.15	0	12	3157	681
21	4	3 "	6.15	to 7.00	0	45	3157	2307

Train No.	Cars on Train.	Headway.	Time.		Time in Service.		H. P.	H. P. hours.
			A. M.	A. M.	hs.	min.		
20	4	4 minutes.	7 00 to 7 24		0	24	3157	1815
21	4	3 "	7 24 to 7 41		0	17	3157	1053
20	4	4 "	7 41 to 9 03		1	22	3157	4209
			P. M.					
10	3	6 "	9 03 to 4 15		7	12	1875	9900
			P. M.					
20	4	4 "	4 15 to 5 07		0	52	3157	2735
22	4	3 "	5 07 to 5 53		0	46	3157	2490
20	4	4 "	5 53 to 6 18		0	20	3157	681
10	4	6 "	6 18 to 9 00		2	47	1540	3880
								15 hs. 51 min.
								29940

Average h. p. per hour $2\frac{1}{3}\frac{1}{4}$ — 1871 h. p.

To which must be added the power consumed in engine and dynamo friction and loss in line.

	1871
Station friction,	300
	2171 h. p.

Evaporation, 7.5 water for 1 lb. of coal.

Hence coal consumption,

$2171 \times 16 \times 2.2 = 88 + 3$ tons for banking, — 41 tons.

at \$2.25, — \$92.25 per day.

From this table it will be seen that for five hours out of the sixteen of daily service 2870 h. p. would be required, or adding 10 per cent. for contingencies, 3157 h. p. during these times, when twenty and twenty-one four-car trains would be in operation under three minutes headway, being reduced to 1250 h. p., or, adding 10 per cent. for contingencies, 1375 h. p., for the seven hours and twelve minutes intervening between 9.03 A. M. and 4.15 P. M., when ten trains of three cars are in service under six minutes headway, while during fifty-four minutes of the early morning, between 5.09 A. M. and 6.03 A. M., and the late evening service of two hours and forty-seven minutes, between 6.18 P. M. and 9 P. M., in which case ten four-car trains are in service, 1400 h. p. would be required, or, again adding 10 per cent., 1540 h. p.

It should be remarked that the power indicated for this service might be very advantageously divided up into four engines of 800 h. p. each, as an examination of the traffic table will show that for only five hours per diem would the whole of them be required, and during the long period of seven hours and twelve minutes, between 9.03 A. M. and 4.15 P. M., two of the engines would be ample for the service.

The results are, however, plotted, and show that the total horse power per diem equals 29,940, or, divided by 16, the number of hours of service, 1871 h. p. per hour, and adding 300 h. p. for dynamo and engine friction, the total should be 2171 h. p. per hour, which, at 2.2 lbs. of coal per horse power per hour, equals 38 tons of fuel consumed per diem, and adding three tons for banking the fires, equals 41 tons, at \$2.25 per net ton, or a total of \$95.25 per diem for fuel alone.

In this connection I should mention that the coal here referred to is a mixture which may be obtained at the dock in New York for about \$1.80 per ton, and which is shown by Barrus in his work entitled "Boiler Tests," to be capable of evaporating $7\frac{1}{2}$ lbs. water per pound in a properly constructed furnace.

There are several makers of compound engines in this country who will guarantee the performance of their engines on 16 lbs. of steam per horse power per hour. It is thus evident that the amount of coal above referred to is a safe one for modern practice on so large a scale. The present locomotives on the Ninth avenue require on an average 40 tons of coal per day for motive power and braking, but experience has shown that it is economical in small locomotive practice to use coal of the best quality; hence the cost of this 40 tons of coal is \$200 per day, or more than double the cost of that for the electric motive system.

It is, of course, necessary to add to the electric estimate a number of charges, such as wages of firemen and engineers at the central station, which would probably bring this item up to about \$150 per diem, considering other items balanced by their practical equivalent in the present service and the cost of repairs, depreciation, etc., to be about equal, which is not far from the fact.

It is thus evident that without considering the future obvious advantages which must necessarily accrue from the use of a great central station equipped with dynamos as before stated, and a conductive system ample for all requirements of the road, that with the comparatively wasteful central station arrangement we have here considered, involving the use of small dynamos of a very old type placed at the extreme end of the conductive system, and suffering from many incidental disadvantages, that it is possible to run the Ninth avenue elevated road with electric motors at an actual and considerable saving of fuel to-day, and if this is not the only example of such a practical demonstration, as oppos-

ed to direct steam propulsion, it is at least the first I have been able to find on record.

The experience of these extended tests and almost innumerable indicator cards, together with countless observations which have been made during the past eight months, have naturally borne fruit in eliminating many objectionable features which only such an examination could develop; and though, as has been said, it is no part of the object of this paper to treat with other than actually accomplished work, it seems but proper to add that the experience gained in this direction has been embodied in another motor, now nearly complete, capable of not only doing such work as is at present accomplished, but of solving, at least for the near future, the vexed problem of extended traffic for the elevated railroads, and, though no actual tests of it have yet been made, there can be little doubt, judging from the performance of the present machine, that it will be capable of towing at least a six-car train on the Ninth avenue elevated road with a considerably increased average speed and with a comparatively low initial effort, due to a change in the proportions of parts and manner of winding, to meet the peculiar conditions shown in the diagram.

In this arrangement the braking of the motor and train has been electrically provided for, also, of course, the lighting, but as this machine is not actually finished, I will not further refer to it other than to call your attention to a part of the proposed plant, namely, the conductor, a section of which has already been placed on the Ninth Avenue elevated road at the curve below 14th street.

There are also economies of braking and in the manipulation of the train, to which I cannot at present further allude, which would, however, in all probability, considerably reduce the working expenses. In this motor the experience which we have had in handling has led to great simplification of the regulating and reversing gear, so that one man may handle the train without the least assistance.

That the plan first suggested by the late Sir William Siemens of braking the train by converting the motor into a dynamo, and so returning a part of the stored up energy of the train to the conductive system, would result in considerable economy, there can be no doubt, provided a thoroughly satisfactory method of practical application were applied, but it is an item that does not appear very conspicuously in any of the quantitative examina-

tions which I have yet seen of any electric system, and while I do not wish to be understood as lightly estimating such an obvious economy, before accepting it as so important a factor as its theoretical consideration by some electricians would indicate, I should like to see a few carefully digested observations of actual performance with motors of high powers.

In conclusion, I trust that if the foregoing facts are not accepted as conclusive proof that the problem is already solved, that they may at least furnish a sufficient amount of tangible material to assist in the early and complete accomplishment of our most sanguine hopes.

DISCUSSION.

THE CHAIRMAN (Vice-President Francis R. Upton):—The question of quick transit in New York City is one of importance to all of us, and I think that this paper should bring forward a number of speakers. We will be pleased to hear remarks.

MR. CHAS. G. CURTIS:—I would like to ask Mr. Daft if he could estimate the average efficiency of the motor as they have been running it, taking fully into account the results obtained.

MR. DAFT:—I have not done that. The object of these tests was to demonstrate that we could run economically in the matter of fuel; and such estimates as we have of its efficiency I am hardly prepared to show to-night. In fact the experiments have not been entirely concluded; and, as I say, this work was intended simply to demonstrate the concrete and absolute economy in the matter of fuel. It is quite easy to deduce from these diagrams a low efficiency in some cases, especially on initial and accelerated effort; but the concrete economy is that which I specially refer to, and that is absolute.

THE CHAIRMAN:—Are there any other questions to be asked or remarks to be made on this subject? The great advance in electrical engineering and the possibility of carrying people, both on surface and elevated roads by means of electricity, is a matter of great importance at the present time.

MR. CURTIS:—Do you pass the entire current through the tread of the driving wheel of the locomotive so that the total current is occupied in increasing the traction.

MR. DAFT:—Yes.

MR. CURTIS:—With regard to the question which Mr. Daft brought out, of how much the calculable total horse-power con-

sumed on the elevated railroads is, I may say that I had a little experience which was rather amusing, because it tends to show how easy it is to make a very great and a very ridiculous error in figuring upon such a problem unless every element is carefully considered. About four years ago, in the winter time, I was very much interested in the subject of running the elevated railroads by electricity, and I had the means of obtaining reliable data as to their speed, coal consumption, and everything that was known at the time, and I figured out in the ordinary way what the average horse power of those locomotives was; for the purpose of getting the average coal consumption. It turned out that the average coal consumption, as I determined it, was about twenty pounds of coal per horse-power hour; and that agreed with a calculation which had been made before, and with the results obtained at that time by electricians concerning the substitution of electricity for steam. When I made that calculation it occurred to me that the element of inertia—the overcoming of the weight or inertia of the train—was a matter that ought to be considered, but I put it aside, assuming that it could not amount to a very considerable portion of the whole power. About a month later something brought the subject to my mind again, and upon revising my calculations and allowing for that element, I found it to be three times as much as the entire tractile effort, assuming the maximum speed on trains at that time as twenty-three miles an hour; taking the weight of the trains and figuring the energy that must be put into the train to overcome this inertia; dividing that by the total distance traveled in a given time (which I think was about 1,100 feet per minute) it showed that about 58 or 60 horse-power was expended simply in overcoming the inertia of the train. That was in addition to the tractile effort. I went over the figures again, very carefully, and I think they were published in the *Electrician and Electrical Engineer*, where the original figures, which were not more than four or five hundred per cent. wrong, had appeared about two months before. About four or five months later, Mr. Campbell wrote me that he was going to make some tests on an elevated railroad locomotive. I did not see the tests, but he sent me the results of them. He found the average horse-power throughout the run to be between 70 and 80, which was within 10 or 15 per cent. of what I figured it. I do not mention it by way of taking the slightest credit for any accuracy in the

calculation, but simply to show how easy it was to figure the whole thing out, and get it right when you gave to every element the importance that it ought to have. The same calculations showed that a great deal of the power, anywhere from 100 to 200 horse-power, was necessary to start the train with the acceleration that they required in order to make schedule time on the elevated railroad. Mr. Campbell's experiments determined the remarkable fact that those locomotives developed a horse-power with about five and a half pounds of coal per hour. These figures were published in the *National Car Builder* at the time, and were so startling that they were denied by a great many civil engineers. I think the question of whether it is better to have a single locomotive to each train or to make each car its own locomotive is a matter that can be determined only by experiment. Of course, as has been said, there are very strong theoretical advantages in favor of having each car its own locomotive. It dispenses with the main locomotive and the heaviest part of the train under the present steam system; and it enables you to increase the length of the train indefinitely. I understood you to say, Mr. Daft, that your machine was about one half the weight of the present locomotive.

MR. DAFT:—It was rather more than one half of the weight. The machine weighs ten tons, and I believe the locomotives on that road weigh a little over eighteen tons. Some of them are a little more than that, but I think that a fair average.

MR. CURTIS:—You only use one rate of gearing?

MR. DAFT:—Only one.

MR. CURTIS:—Have you any friction clutch?

MR. DAFT:—Nothing of the kind on the present motor.

MR. CURTIS:—May I ask if you know about how the counter-electromotive force compares with the direct when you are running at full speed?

MR. DAFT:—I have not the figures here to-night, and cannot give you those particulars now. I have particularly confined myself to this question of coal economy, and I propose, if I have the opportunity later, to deal with the other part of the subject.

MR. JOSEPH WETZLER:—Mr. Daft alluded several times to the effect of the absence of brakes on his train, and also states that in the new train which he is equipping he proposes to introduce proper brakes. I would like to inquire what form those brakes will take, and whether they are direct electric brakes, or those in

which electricity is merely used as an auxiliary, the momentum of the train being utilized to create a vacuum, as has already been done.

MR. DAFT:—The electricity is an auxiliary, but I am not at liberty to enter into details at present.

MR. GEO. B. PRESCOTT, JR.:—It seems to me that in the question of the transmission of power to a great distance, the loss of energy in the conductors themselves is a very important factor, and is one that Mr. Daft has not touched upon. I think it would be interesting to know the initial potential that he used, and what he would consider the practical potential for a line the length of the elevated road, and also how far apart the generating stations would have to be.

MR. DAFT:—I did not propose to enter into that question at all to-night, as that was not a part of this paper. It was simply as I stated repeatedly, to show this concrete economy. I propose later, having an opportunity, to deal with the other part of the subject, and especially when a motor of another type, to which I have alluded, is put on the track. But I may say that I have to some extent, on this particular question, discarded the practice I had before adopted and used a very much higher potential, and that the potential which has been used here is considerably higher than I have made it a practice to use anywhere else, and for many reasons—one of them being that the conductor system is so far out of the reach of the public, on the elevated structure, that it seems hardly possible that any danger can result from it. I have used potentials which are sufficiently high to obtain the necessary economy, without using a copper mine on the track.

MR. CURTIS:—I presume you have not in mind the relation between horse power and the number of miles to be covered, that is, what amount of horse-power is distributed over a mile.

MR. DAFT:—No; I have not.

THE CHAIRMAN:—I notice that Prof. Anthony is here and we would like to hear from him.

PROF. W. A. ANTHONY:—Mr. President: I came here to listen. I have not had much to do with electrical traction, and have not very much to say on the subject. I would rather listen to what others are saying; but I would like to ask Mr. Daft if I understood him correctly with regard to the gradient which he has overcome by means of the electro motor. I understood him to

say that he has had an electro motor run up a gradient of 45 degrees. Is that so?

MR. DAFT:—Yes.

THE CHAIRMAN:—We would like to hear from Mr. Mailloux.

MR. C. O. MAILLOUX:—I would like to plead very nearly the same excuse that Prof. Anthony has, namely, that I came here principally to listen. My experience with electrical traction has not been in that same line, and I have maintained with regard to it what might be called an expectant attitude; for the reason that while I did not for one moment regard the project of substituting electricity for steam upon the elevated roads, or upon a scale of equal magnitude as an unfeasible or impracticable thing, yet I doubted if the art had advanced sufficiently to enable us to carry out the engineering details of it with sufficient accuracy in order to obtain industrial results that would lead to a successful competition with steam. I am very glad to see the progress in that direction which is now made public in the able paper read by Mr. Daft, this evening. I am surprised to see that more advance in that direction has been made than I had anticipated. At the same time, I am prepared to say, that I still remain somewhat conservative: that while I do not for one moment doubt that success will ultimately be ours, in that field as well as in others, yet we have a great deal of ground to cover before we can relegate the locomotive to the shelves of old and ancient models. I was reading in a Spanish paper recently, an article wherein this anticipated substitution of electricity for steam is spoken of in very rhapsodical and enthusiastic terms, and wherein it is said that we should soon see the steam engine entirely done away with, and shown to our children as a curiosity. I do not think that is likely to be the case. I think that it will be some time before we have overcome what might be called the inertia of the railroad people—before we have overcome their inborn prejudices. It is only a few days ago that I had a conversation with a person interested in the elevated railroad management in some mechanical or technical capacity, and I had occasion to notice what a strong prejudice there is against anything but steam for the purposes of traction in that service. That prejudice is the result not only of a training of perhaps thirty or forty years upon the part of the individual in the art of applying steam to that particular purpose, either upon elevated or surface roads, but also of the observation of electric railway experiments and trials which have been made

in various parts of the country, and I might say of the world; and which not being unqualified successes have been very eagerly construed by railway people as being proof of unqualified failure. In order to overcome this long standing prejudice, therefore, we shall have to be sure, and make assurance doubly sure, that everything is all right before we go ahead, in order to be certain that we can command the way, and meet successfully that which now holds possession of the field—steam—and guide him out of it. I would like to ask Mr. Daft in regard to the difficulties (if I may so term them) of conveying current to the motors where the network of tracks is at all complicated by switches. There are certain parts of the system where there is a considerable number of switches and sidings, where I can conceive that there would necessarily be some difficulty in the conducting of current to the motors.

MR. DAFT:—We have not experienced any special difficulties in that direction, although, of course, we have not had entire possession of the track. It has been necessary to leave the track in such condition that the steam motors could operate. But we have, except in one or two instances, much less difficulty by using a contact brush on both sides of the motor, and where the continuity of the conductor was broken on one side we could almost invariably make it good on the other. That is true of almost every switch that we have had to encounter on the system as yet. Even at 50th St., where the switching is more than usually complicated, we have so little difficulty that only in one or two instances have we had to bridge a distance of a few feet (I think in one case five or six feet) by momentum.

PROF. ANTHONY:—It has always been my belief that we should at some time reach the solution of this problem of electrical traction on the elevated railroad. Ever since the elevated railroad started, or ever since we began to use electrical motors for traction at all, it has been my belief that we should at some time reach the consummation of that result. The difficulties are not electrical. It is easy enough to build an electrical motor which shall have the power necessary to pull the train. The difficulties it seems to me are mechanical and economical. When we take the problem into consideration, the question is, not, is it possible to do it, but, is it possible to construct an apparatus cheaply enough, and to make it operate cheaply enough to compete with steam locomotives. It seems to me that Mr. Daft is doing a great

deal to solve that part of the problem. (Applause.) There are a great many problems that come in here to be studied in connection with it. Mr. Daft has referred to one difficulty—that of braking the trains in these early experiments. Of course, some sort of an electric brake must be devised. It is not going to be easy to put an air brake on an electrical train, although we might, perhaps, use an electric motor for compressing the air to use with ordinary brakes, but it will probably be found better to use some electrical system; and such a system must be devised. We must be able to handle the train exactly as we do the steam train. We must be able to make our stops and our starts as quickly, in order that there be no more lost time than at present, so that the difficulties, as it seems to me, are not in simply constructing the electric motor, but in overcoming the various mechanical difficulties which are to be met with in the problem, and in fact in answering all the requirements of the service. As to the economical question I may, perhaps, say a word or two. I have had nothing to do with the study of electrical traction, and have never given it very much thought except in looking over the results which have been reached by others. I have on one or two occasions computed the cost of transmitting power over considerable distances with stationary motors, and I have been somewhat surprised at the results. Assuming 2000 volts as the potential, I have found that, when we come to get up into hundreds of horse power, the cost of the plant becomes something rather enormous; and when the question has arisen of transmitting a water-power over a distance of five or ten miles it does come out every time that a man could locate a steam engine at the point where he wants the power, and if he could get coal at \$4.00 per ton, run the whole thing at a less cost, taking into account interest and depreciation of plant, than he could by putting in an electric motor, dynamo and water motor, for transmitting the power.

MR. MAILLOUX:—I wish to endorse Prof. Anthony's statement. It was of special interest to me, because it was a statement of my own experience. In making my observations with regard to the progress in the art of engineering, I should perhaps have said that I put the emphasis on the word *engineering*, and particularly on the mechanical part of it, and that would bring my observation at once in accord with Prof. Anthony's; because it is particularly on that side of it, and with regard to the production of the manufacturing process by which the cost of turning out ma-

chinery can be reduced, that I have particular reference to. There is no doubt that the cost which the contractor, engineer or company must provide for in order to make a profit on each electric equipment, is considerably higher than the cost of an equipment by steam or other well-known methods under the same circumstances. That is what I meant by progress in the art. I mean the general progress which is the result of evolution, and which has enabled the steam engine manufacturer and the manufacturer of lathes and other machinery to reduce the cost three or four times in a period of twenty-five or thirty years, and to simplify and perfect the construction, and to make a smaller weight of metal and a fewer number of parts perform the same functions equally well, and in most instances far better. Those are the general factors of progress in the art which we must look for in order to accomplish the results. Now, in regard to the question of momentum, I think that the point made by Mr. Daft is a very important one indeed, as is also that made by Mr. Curtis. I can scarcely conceive of any more important factor to deal with in the problem of engineering and in the system of electrical traction, whether on the surface or the elevated railroads, than that of momentum. Because it has such enormous limits, bearing on the cost of power under different conditions, the size of car, the number of miles it can be run, and a great many similar results which are so largely dependent upon it. But there is probably no more influential condition than the distances between the stops. As Mr. Daft has shown, on the elevated roads, the grade happens to be placed in some instances in such a way that the momentum cannot be utilized; but on surface roads I have seen instances where the momentum of trains could be utilized; and only those who have tried it can get an adequate idea of the amount of energy which is stored in the form of momentum in a moving body. Where the gradient is not too severe, the car is sometimes enabled to run for a long distance, and even to come to a comparative stop, and then upon being relieved from the brake pressure, go on with a perceptible rate of speed, and in that way a great deal of economy of energy can be exercised. This is particularly true with regard to suburban routes where stops are not so frequent. But in cities where the stations are located very closely, all this energy which otherwise might be utilized in propelling the car is necessarily lost; and not only that, but we must provide a means of starting quickly. That is

the secret of braking a car. We extract from it the energy which exists there in the form of momentum. Of course, if we could find means of utilizing it at the same time, it would be all the better; but I doubt whether it is proper for us to consider that problem at present. It will probably come up later.

THE CHAIRMAN:—We shall be glad to hear from Mr. Martin.

MR. MARTIN:—I think that we owe a great deal to Mr. Daft for the extreme care, and the large amount of work which he has brought to bear upon the paper which we have heard this evening. My friend, Mr. Curtis, had an idea that there were certain things that Mr. Daft might have told us which he did not tell us. In listening to such a paper as this, we should bear in mind that such tests as these are very often made at great expense, and that the results obtained might well be regarded as being the exclusive property of those who make them; and we should appreciate the public spirit, and the desire to advance the profession of those who lay before us such elaborate, careful and exhaustive results and figures as we have had this evening. (Applause.) With regard to some of Mr. Daft's statements I think he will allow me to say that four or five years ago I had an opportunity of seeing him make some of the tests to which he referred; and then my own doubts as to the results which he obtained were as great as those of anybody, until I actually saw the car ascend the grade that he speaks of, with, I think, himself, on board. At that time the opportunity of operating on the New York elevated roads seemed very remote; in fact it seemed a question which it was idle to discuss—just as now it seems idle to discuss the probability of running the New York Central road by electricity. But I think that we have done something more than "mark time" in the four or five years which have elapsed since I saw Mr. Daft make those experiments; for we are now operating a great many miles of track in this country with electric motors. It is true that we are not operating on the elevated system, but I believe that the day is not very far distant when the elevated roads will certainly be placed at our disposal, to do our worst with, and I have no doubt that Mr. Daft will bear his share in the honor and glory of that time. I think to New Yorkers it will be a very pleasant and agreeable time when we shall have dispensed not only with steam, but with the horses which now afflict us in this city. (Applause.) It may be a little bit poetical, but as I sat and listened to the horses out there in the street it seemed to me

they were doing their best to drown Mr. Daft's voice (Laughter), and to prevent us realizing the full scope and importance of the remarkable tribute which he was laying before us. I had the misfortune two or three years ago to hire a flat near the track of the elevated road. It was up town, in the neighborhood of Central Park, and it seemed to me very desirable. I hired it in winter time when the windows were closed, but when the summer came I realized that the situation was not as desirable as it seemed in winter; and I had opportunities of studying very closely and very exhaustively the effect of steam upon the elevated roads, and I satisfied myself, as any one who travels on the road must be satisfied, that in electricity alone are we to find the solution of our difficulties and troubles; and in electricity alone shall we find such a system as is worthy of the city of New York.

MR. CURTIS:—Before you make your motion, I beg to say a few words. I did not mean to imply that there was anything which Mr. Daft might have added to his paper, germane to the discussion, which he left out. I simply thought that, as a very interesting feature connected with his experiments, the counter-electromotive force might show something as to general efficiency.

MR. DAFT:—I am quite sure that Mr. Curtis would not say anything that was discourteous, and I did not so interpret anything that he said.

MR. MARTIN:—I simply wished to express our appreciation of what we have had, in as concrete form as possible; and therefore I move that our thanks be presented to Mr. Daft for his interesting paper.

THE CHAIRMAN:—It gives me great pleasure to put the motion. I think we owe our thanks to Mr. Daft and to others, who offer us the results of work done, as in this case. This represents, as you see, a work extending over months, and the expenditure of much money, and the results are offered to us in a form which will be useful; giving us many important facts, and carrying us to a higher plane of knowledge.

The motion of thanks was unanimously adopted; and the meeting then adjourned.

A paper read before the 37th meeting of the American Institute of Electrical Engineers, New York, September 10, 1889, and discussion thereon, Vice-President T. C. Martin in the Chair.

ALTERNATING CURRENT MOTORS: THE EVOLUTION OF A NEW TYPE.

BY LIEUT. F. JARVIS PATTEN.

On giving our secretary the title of this paper it was my purpose to treat the subject in a broader light, and to show the progressive steps in a series of experiments which led eventually to the type of machine that I shall bring to your notice this evening. The recent and urgent claims of other work have rendered such a treatment impossible at present, and I shall limit the paper to a description of a new alternating current motor, one form of which is shown in the accompanying drawings.

The place that the alternating current electric motor is destined to fill in the industrial arts is familiar to you all, and the various ways known to the scientific world by which such machines may be rendered operative have been ably considered and elaborately discussed in the Institute papers of the past two years by Prof. Thomson, Dr. Duncan and Mr. Tesla. We are thus all more or less acquainted with the prominent difficulties of the problem.

My experience, in common with that of my predecessors, teaches that the alternating current motor has a strong and persistent disposition to stand still, and when persuaded to motion is apt to be a sort of "go as you please" machine and asserts its inherent right to turn in either direction indifferently, direction of rotation in some cases being purely a matter of chance. I shall not have much to say about efficiency, as my experiments

with large machines are not sufficiently advanced to furnish any reliable data, but I will endeavor to give a general solution of the problem designed to meet the following conditions of practice:

1st. A machine that will start itself independently of the speed of the generator or number of alternations of current per unit of time.

2d. A machine that has but one direction of rotation and cannot reverse under any conditions of current alternation.

3d. A machine that is not necessarily synchronous with the generator, revolution for revolution.

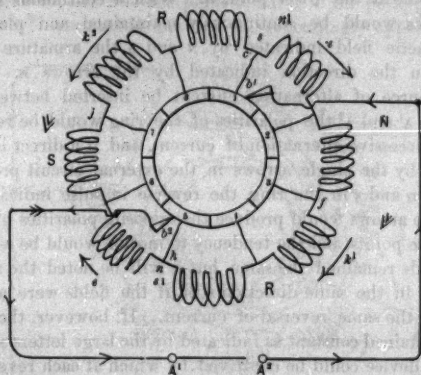


Fig. 1.

4th. A machine in which reversals of current direction do not produce corresponding reversals of magnetism in any iron part, when the machine is in motion at its normal speed and maximum efficiency.

5th. A machine of simple form having an ordinary continuous wound armature revolving in a single or two pole field.

Referring now to the figures which are simply diagrams of the circuits and operative parts we have in Fig. 1 an ordinary closed circuit armature shown as a Gramme ring merely for convenience of illustration, the points of the winding intermediate between the eight coils being connected in the usual way to the eight segments or bars of an ordinary Gramme collector, and it may be well in passing to note here the functions of this collector.

It is not a commutator in the strict sense of that term as it does not rectify or redirect reverse or opposed currents. If the brushes b^1 and b^2 were held upon the outside wire of the ring, the same results would follow, and the Gramme collector properly so called simply transfers the brush contact from point to point of the ring winding. If a source of direct current be interposed between the terminals A^1 and A^2 , current will flow continuously from brush b^1 to b^2 downward through the right and left hand halves of the ring in the direction of the arrows k^1 and k^2 , making say a south pole in the ring at the upper point s , and a north pole at the lower point n . With a continuous current these poles would be continuously maintained and placed in the magnetic field indicated by N and S the armature would revolve in the direction indicated by the arrows E , E . If now a source of alternating current be inserted between the terminals A^1 and A^2 the polarities of the ring would be reversed at each successive alternation of current, and if a direct impulse indicated by the single arrows in the external circuit produced the poles n and s in the ring, the reverse impulse indicated by the double arrows would produce the opposite polarities n^1 and s^1 at the same points, and the tendency to motion would be reversed if the fields remained the same, but it will be noted the motion would be in the same direction still, if the fields were also reversed by the same reversal of current. If, however, the fields were maintained constant as indicated by the large letters N and S and some device could be contrived by which at each reversal of the alternating current, the brushes b^1 and b^2 could be made to change position, either mechanically or otherwise, then with an alternating current a constant polarity s and n would be maintained at the upper and lower points of the ring—for then a direct impulse starting from A^1 to the right would enter the ring through the brush b^1 flowing down both sides in the direction of the arrows k^1 and k^2 out through brush b^2 and back to the source at A^1 . The reverse impulse indicated by the double arrows would start from A^1 to the left, going to brush b^2 ; and if we now suppose this to have changed places with the brush b^1 the reverse current would then enter the ring at s and flowing down both sides in the direction of the arrows k^1 and k^2 would leave through n and the brush b^1 , and so back to the source A^2 maintaining the polarity of the ring the same as before. If the brushes could be thus changed at each alternation, the polarity of the ring would be

maintained constant with an alternating current. While, however, it is quite impracticable to thus cause the brushes to change position mechanically at each reversal of current, it is perfectly feasible to produce the same effect without the mechanical change. The means of accomplishing this result are indicated in Fig. 2, which is identical with Fig. 1 with a single exception. There are eight coils as before, and eight bars in the collector; the odd number bars 1, 3, 5 and 7 are connected to the same points of the ring as before *c*, *f*, *h* and *j*, but the even numbered bars 2, 4, 6, 8 are connected respectively to points of the ring diametrically opposite them, bar 2 to the point *d*, bar 4 to the point *g*, and so on each even numbered bar to a correspondingly opposite point

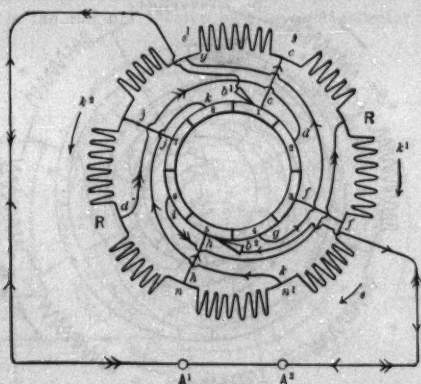


Fig. 2.

of the winding. If now a source of alternating current be interposed between the terminals A^1 and A^2 and we make the single supposition that the ring shall turn through an arc of the circumference equal to that covered by one bar of the collector during each alternation of current, we shall still maintain a constant polarity at the upper and lower points of the ring without causing the brushes to change position mechanically.

Thus a positive impulse starting from A^1 to the left and indicated by single arrows enters the ring at *b* flows down both sides to *n* producing the ring polarities *s* and *n*, out brush *b* and back to source at A^2 . The reverse impulse being in the opposite

direction will start from A^2 to the right, go to brush b^2 , which we will now suppose bearing on segment 4 of the collector, whence it will go by the inverse connection to the opposite point a^1 of the ring, then down both sides in the same direction as before to the point a^1 thence back to the opposite segment 8 out brush b^1 now bearing on this segment, and back to source at A^1 .

The reverse currents therefore under the assumed conditions are caused to maintain a constant polarity in the ring so that in a constant field its tendency to motion would always be in the same direction with an alternating current in the armature. It will be further noted that the alternating current is not redirected or commuted in the strict sense of the word, and we may enun-

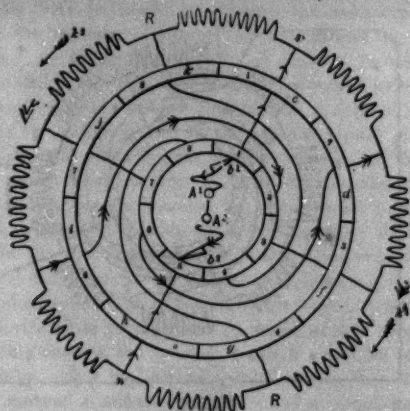


Fig. 3.

ciate the fundamental principle which underlies the construction of this type of machine as follows:

The poles of any closed circuit may be maintained constant with an alternating current by causing opposite impulses to traverse the circuit in opposite directions. The direct and inverse connections shown in Fig. 2 have precisely this effect, when, as supposed, a single bar of the collector passes under the brushes at each reversal of current. The connections $c a, d d, f f$, etc. in Fig. 2 may have any form, and other bars may be interposed between their extremities without affecting in any way their functions as connectors. This step is shown in Fig. 3

where another collector bar $1c$, $2d$, $3f$, etc., is inserted in each of the connections $c c$, $d d$, etc., of Fig. 3, thus making another collector shown outside the first to avoid confusion of the drawing, while for the same reason the source of alternating current $\Delta^1 \Delta^2$ is placed inside the inner ring. The polarities s and n of the ring being maintained constant, as previously described, with an alternating current, and as current is constant in direction from s downward through the right and left hand halves of the ring to n , so must necessarily any current be constant in direction which is led from brushes through any other circuit connected to the segments $1c$ and $5h$ of the outer collector; a field circuit of constant direction may therefore be shunted from this outside collector. This is shown in Fig. 4, in which twelve coils are shown in the ring and twelve bars in each collector connected

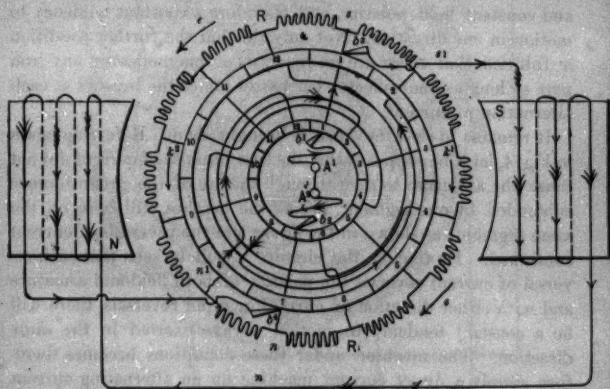


Fig. 4.

alternately direct and inverse as before. Tracing now two opposite impulses of current we have the first indicated by the single arrows from source Δ^1 to segment 1 of the inner collector, thence to segment 1 of outer collector, where the current divides, part going down the right and left hand halves of the ring to n^1 and part out brush b^1 through the field circuit, making the poles n and s back to brush b^1 segment 7 of outer and segment 7 of inner collector to the terminal Δ^2 of source. If the armature be supposed now to turn through the space covered by one col-

lector bar the reverse impulse can be traced as follows: Starting at A^2 in the opposite direction to brush b^2 now bearing on segment 8 of the inner collector thence through the reverse connection to segment 2 of the outer collector, now under brush b^2 where the current divides, going part as before down the right and left halves of the ring, making a south pole at s^1 and a north pole at n^1 as before, and the other part out of brush b^2 through the field circuit in the same direction as before, back to brush b^1 now on segment 8 of the outer ring, thence through the reverse connection back to segment 2 of the inner ring, now in bearing with brush b^1 and so returning to the source at A^1 . Thus the two impulses of opposite direction have been made to transverse both armature and field circuits in the same direction. We have therefore with an alternating current constant armature polarity and constant field polarity, and therefore a constant tendency to motion in one direction. Not only this but the further condition is fulfilled that there are no reversals of magnetism in any iron part so long as one collector bar passes under the brushes at each alternation of current.

It remains to show how this is brought about. Referring again to Fig. 4, let it be supposed that the first impulse of current did not cause the armature to turn through the arc of the circumference subtended by one segment, but all the brushes still bore on the same segments as shown in the figure and the reversals of current continued. By tracing the circuits it will be seen that each reversal of current reverses the polarity of both field and armature and with either direction of current or rapid reversals, there will be a constant tendency to motion always exerted in the same direction. The machine under these conditions becomes therefore simply a direct current machine on an alternating current circuit with a constant tendency to start in one direction. Assuming the machine therefore self-starting, it will continually gain in speed until the condition is fulfilled of one segment passing the brushes at each alternation, for it then becomes in the broad sense a synchronous alternating motor, the current then produces no reversals of magnetism, and there is a true alternating current in the armature circuit, producing, however, no reversal of armature polarity; and a current of constant direction in the field. Under these conditions the motor is self-regulating, moving at a constant speed and with a maximum rotary effort.

It is not, however, essential that one bar should pass the brush at each alternation, as any number may be caused to do this, depending upon the speed required and the number of coils upon the armature. This is illustrated in Fig. 5, where the complete machine is shown. There are twenty-four coils in the armature, twenty-four bars in the outside collector and thirty-two bars in

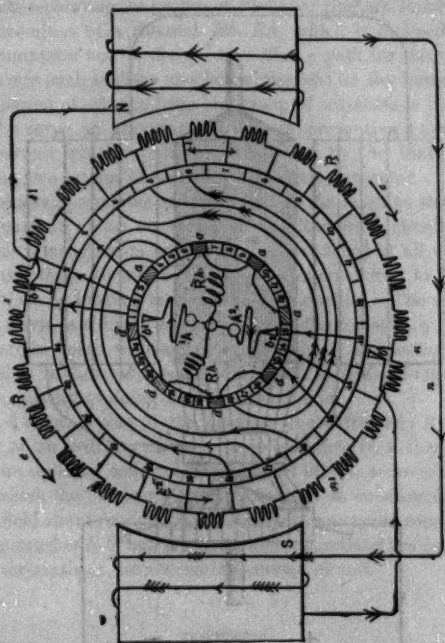


Fig. 5.

the inside one, this latter being composed of twenty-four connecting and eight insulating bars. The connecting bars of the inner ring are numbered to correspond with those of the outer ring around to the right from one to twenty-four:—the insulating bars drawn shaded, separate the others into groups of three. In this machine three segments, 1, 2, 3, in the outer ring, are connected direct to the corresponding segments, 1, 2, 3, of the inner

ring, likewise the opposite three, 13, 14, 15, of one ring, are connected direct to 13, 14, 15 of the other. The next group of three is connected inversely, 4, 5, 6 of the outer ring, to the diametrically opposite bars, 16, 17 and 18 of the inner ring, and the corresponding opposite group, 16, 17, 18, of the outer ring, is likewise connected inversely to the diametrically opposite group, 4, 5 and

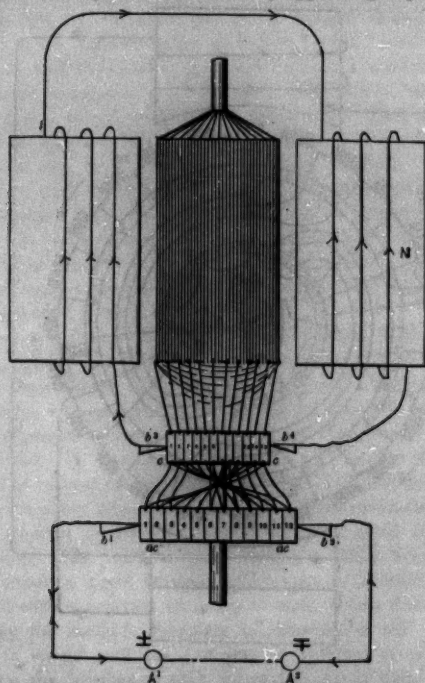


Fig. 6.

6 of the inner ring. The remaining segments are connected in the same manner, but the connections are omitted to avoid confusion of the drawing. The operation of the machine is evidently the same as that shown in Fig. 4, except that the required conditions are fulfilled in this instance when three bars of the collector pass under the ring at each alternation of current, and

as there are twenty-four segments arranged in groups of three, the machine at its normal speed would make one revolution for every eight alternations of current, and connected in a circuit supplied with 16,000 reversals per minute, its normal speed would be 1999 — 2000 per minute, and with 48 segments arranged in groups of three its speed would be 1000 per minute. The blank segments separating the groups of the inner ring are connected to the extremities of a rheostat *Rh. Rh.* which is inclosed inside the commutator and is designed to offer a path for the alternating current such as there may be and prevent its absolute rupture at the period of change from one group of segments to the next; they also serve an important purpose in preventing a dangerous short circuit which would be occasioned by the inner brush bridging two groups of segments oppositely connected.

It follows as a matter of course that as the machine starts as a direct current motor connected in an alternating circuit, rapid reversals of magnetism will at first be produced in all the iron cores and these should be made of laminated iron to prevent undue loss by heating at the period of starting. The machine in fact starts as a direct current motor and automatically changes at a certain speed to a sort of synchronously alternating motor. It reaches its normal speed at this point, is then self-regulating, and its capacity of doing work is a maximum.

Fig. 6 shows a plan of the machine as constructed; it consists simply of an ordinary closed circuit armature in a single field; *c c* is the ordinary collector really a part of the armature circuit from which the brushes *b¹ b²* take a current of constant direction to the field shunt; *a a, a c* is the reversely connected commutator and the brushes *b¹ b²* bearing upon this commutator are connected to the terminals of the alternating current circuit.

DISCUSSION.

LIEUTENANT PATTEN, continuing orally:—I might add to the paper the fact that the inner commutator, the one which is the ordinary commutator of the Gramme ring winding, does not perform the ordinary functions, as the brushes bearing on this collector require no adjustment, it being merely a rubbing contact, from which the shunt field current is taken as a derivation to the main circuit of the machine. With that exception, I think the machine is fully explained in the paper.

MR. C. O. MAILLOUX:—I would like to ask Lieutenant Patten whether sparking occurs to an injurious extent or not.

LIEUTENANT PATTEN:—The sparking being due to the electromotive force at the point of breaking, it will necessarily occur during the starting of such a machine and more than ordinarily when it is out of synchronism with the alternating current. At the outset, it can be easily seen that the alternating current is liable to be broken at a point where the electromotive force is high, and therefore the sparking would be very violent. I have endeavored to obviate the trouble due to that cause, by the device shown in Fig. 5. If you will notice the circuits carefully, it will be seen that the circuit of the alternating current is never broken. If the brush comes on to one of the dead segments or shaded segments connected with the rheostat before the alternating wave has come to zero, it finds a path which is at first in parallel with the machine circuits and then becomes a separate path for the alternating current during its change, whether this change begins at a high or at a low electromotive force. Of course, as the machine starts, this may happen at any period of the wave, and the brushes passing over these segments connect with the resistance at the end of the group, and before it has left the group the current is already short circuited through this rheostat. So that the alternating current always has a path and the sparking will not be excessive, judging from what little experience I have had.

MR. R. S. DOBBIE:—I would like to inquire whether the field magnets are laminated, and whether the lamination would be necessary only while the machine was starting up as an alternating motor or before the synchronism is attained. I would also like to ask if the maximum torque of a machine is at one-third speed, and how that compares with the torque of the same machine at full speed when the synchronism is attained.

LIEUTENANT PATTEN:—In answer to the first point I would say that there is no essential reason for laminating the field magnets for any other purpose, but it has been shown by quite conclusive experiments that a laminated machine has a very definite neutral line of field, which makes it better for taking the direct current to feed the field, and I avoid the necessity of having two sets of movable brushes. With respect to the other point, the torque of such a machine depends of course, entirely on its keeping in synchronism, and the result of the departure from

that point is well known to all. That is the limit of the strain that can be exerted. When that is exerted the machine will stop; it will not then continue as a direct current machine.

MR. DOBBIE:—My reason for asking that question was to find out if the motor will start on a full load.

LIEUTENANT PATTEN:—No; it will not.

MR. LEMUEL WM. SERRELL:—I would like to ask how the currents are short-circuited through the rheostat when the ends of the rheostat are connected to the insulated blocks in the commutator.

LIEUTENANT PATTEN:—The question is a pertinent one inasmuch as the term "insulator" was used in the paper. They are not insulated segments in the true sense of the word. They are all connected with each other and are of conducting material. The mistake is my own entirely in using the word "insulated" in any sense. The insulating segments referred to are the same kind of segments as the others. They are simply other segments not connected to the machine circuits and a little narrower than the others.

MR. SERRELL:—The shaded portions, as I understand, are insulated blocks, but as is now explained, the shaded portion indicates a metallic connection separated from the rest of the commutator.

LIEUTENANT PATTEN:—No; they are simply segments, the same as the others, but are connected to an interior rheostat, which is not in the circuit of the machine. I think, as has just been suggested to me, that they should be called "isolating" segments instead of insulating segments. They are segments not connected with the circuit of the machine, but simply to the rheostat, which is shown in the drawing, and this rheostat is intended to take the current at the time the brush leaves the group which is connected with the machine circuits and so prevent sparking.

MR. H. WARD LEONARD:—I would like to inquire whether the interruption of the current in the field is going to occasion any heating of the field or loss of efficiency.

LIEUTENANT PATTEN:—I might say in reply to that and answer at the same time a good many questions that might be advanced of a kindred nature, that my experiments have been very limited and that it would require considerable investigation to determine that point definitely. I have no doubt that it does limit the action of the field, but to what degree I do not know. But the

current is broken when the machine is in synchronism at a point near its zero value. Of course, at 16,000 alternations per minute the interruptions are so short that the field could not readily lose its magnetism, but whenever there is a break of the current there must be some slight loss due to that.

DR. ALLEN V. GARRATT:—Another question in regard to the rheostat. Is the resistance of those coils gotten at by experiments, and if so, what relation do they bear to the resistance of the machine itself?

LIEUTENANT PATTEN:—So far, I have attempted to make the rheostat simply equal to the resistance of the machine, so that there would be as little change in the strength of the current as possible.

MR. MAILLOUX:—Is the resistance re-actionary or simply dead?

LIEUTENANT PATTEN:—So far the resistance in the commutator is a dead resistance simply. It might theoretically be made to advantage of the re-active kind.

MR. MAILLOUX:—I should think that a machine of this kind, although it is of great theoretical interest and is an evidence of striking ingenuity, would be open to a defect arising from the fact that the current is a wavy one, no matter how rapid the periodicity is. There is always a very short time when there is no current. We may consider that the magnetizing current through the shunt is a succession of waves. Consequently there would be a tendency for the magnetism to rise and fall. If the magnetic core is laminated and of soft iron, I think that it will be able to rise and fall quite rapidly enough to follow the fluctuations of the current. We know that it does so in transformers. Of course there is a slight reaction in the substance of the iron itself—its “viscosity,” due to hysteresis; at the same time it is not sufficiently great to interfere with the rise and fall of the magnetism, and the more perfectly the core is laminated the more rapidly the rise and fall would take place. It seems to me there would be quite a material loss under certain conditions, and also a loss due to the reactions following from mutual induction in the armature itself, because even when running at synchronism the current in the armature would be a succession of rises and falls, and although the magnetism of the armature is not reversed, yet the current is reversed through the coils, and is constantly rising and falling at a very rapid rate. I should think that the loss due to mutual induction, particularly

in the presence of a magnetic body, such as the armature core, would lead to a very important source of loss, and I should not expect that a motor built on that principle would show the efficiency of other forms, for instance, as those suggested by Leblanc in France, and Mr. Mordey in England.

LIEUTENANT PATTEN:—I have only to say in reply to that, that there is one evident misconception about the direction of current in the armature circuit. It is always the same. As to what has been said with reference to the induction due to the rise and fall of current, such loss is contemplated, and it is difficult to make out of an alternating current anything that does not vary. The essential fact, however, is that the current at work is due not only to the maximum and zero values of the electromotive force exerted, but to the current which is the result of the mean electric force. I do not recall any machine described by Leblanc, except those that he has referred to as Mr. Tesla's and Prof. Thomson's earlier form of motor. Beyond them I do



Fig. 7.

not recall any machine in which these difficulties are not equally present.

MR. E. P. CLARK:—I do not think that the rise and fall has very much influence, because when the armature is revolving at a high rate of speed it is the same as a continuous current dynamo. As long as the speed is constant the current will be very nearly the same. There will be very little rise and fall to it, due to the rise and fall of the alternating current.

LIEUTENANT PATTEN:—The current in the field will necessarily be a re-directed current. It would be represented graphically in the form I have drawn on the board (Fig. 7). The commutated current at work, or the electromotive force, to speak more strictly, would be cut off at the point a , we will say, if the machine is in synchronism at points a^1 and a^2 , the interval would be a period of no current. The loss spoken of by Mr. Mailloux will exist during such a slight period of no current whatever, as occurs at this point. I think that a solid field would not probably

give up its magnetism during that short period of time. A closely laminated field might do so.⁴

MR. LEONARD:—I should like to ask if, when the load is removed, there would be a tendency to race?

LIEUTENANT PATTEN:—The limit of load in such machines is that which is required to throw it out by a full quarter of a period, and this is reduced to a quarter of a group of segments. If the load is lifted off it cannot, unless the conditions of current change suddenly, go beyond its ordinary synchronous rate.

MR. LEONARD:—Can it race?

LIEUTENANT PATTEN:—I think not. The tendency of course is, if it races, to go to the double synchronism. It has to go to the double speed or the quadruple, or else at the single speed at which it is synchronous.

MR. MAILLOUX:—I do not think that Lieut. Patten has made quite clear the influence at work to maintain the speed constant when the load is increased or decreased—the exact action which takes place by which the torque is changed.

LIEUTENANT PATTEN:—The action of this machine is not different from that of an ordinary alternating current motor, where its maximum electromotive force is exerted when it is in synchronism within a quarter period of that of the generator. If it is overloaded beyond that point it comes to a state of rest or short-circuits the armature and it burns up.

MR. EDWARD P. THOMPSON:—The question has occurred to me whether this new type of motor is also a dynamo, and what kind of current would be generated by it?

LIEUTENANT PATTEN:—I have never driven the machine backwards, but I discussed this question with Mr. Seely in the Patent Office, and it was first supposed by him that the machine was not a "dynamo and electric motor" as I had termed it in the specification. But we finally came to the conclusion that it was. The chief objection is that a self-exciting dynamo must have a continuous current to excite its field, and it must be an increasing current. The unfortunate thing about this machine is that it has not an increasing current. The question arises as to whether there would be a sufficient continuity of current in the machine with this short circuit to make it a dynamo. I have not driven it backwards, and the theoretical result can be arrived at as readily by my associates as by myself. I think it would be a dynamo, but of low efficiency.

MR. LEONARD:—I should like to ask Lieutenant Patten if he would kindly give us some description of the performance and sizes of the machines that he has made thus far.

LIEUTENANT PATTEN:—Those I have made are too small to give any data which would indicate any efficiency worth talking about.

MR. LEONARD:—What voltage did you work upon?

LIEUTENANT PATTEN:—100.

THE CHAIRMAN:—There are several points in this discussion which should be elucidated, and if any gentlemen has questions to ask, or theories to ventilate, or ingenious motors of his own to describe, I trust he will have no reluctance in doing so. There

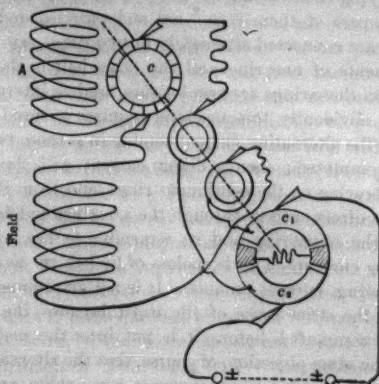


Fig. 8.

are several gentlemen here whom we all know to be interested in the subject; I do not think that they should make it requisite for me to call upon them. We would be very glad to hear from them, and although some of them are here with us for the first time, I do not think that they need have any hesitancy in letting us hear from them.

LIEUTENANT PATTEN:—In the meantime I will draw the Mordey machine on the board and show the difference. (Fig. 8 was placed on the board.) The device for rectification is fixed on the spindle of the moving machine. The dotted line represents the spindle of the machine. It is the commutator of an

ordinary armature which is shown here. This being the armature circuit we will trace it simply as a closed coil from the upper point to the opposite point of the commutator and thence to the field. On the same spindle with this armature is placed another commutator, which is shown here in two parts. The upper and the lower halves are separated by isolated segments connected to a rheostat such as I have described this evening. It is shown this way, but in reality there are for each pair of segments a corresponding pair of isolating segments connected with the rheostat, so that after the brush passes one segment it connects with the rheostat, and so on. At the bottom is the source of the alternating current. These terminals go to the two brushes; bearing on the rectifying commutator which is broken up into alternating segments, part of them connected and part isolated. The live segments are connected alternately to two rings, say one half to the segments of one ring and the other half to the other ring. Bearing on these rings are two brushes used as intermediate connections. Evidently this machine requires a speed of rotation such that the alternating current coming in at these two terminals will be commuted; then a direct current will flow from the brushes, bearing on the continuous rings, and from these brushes we have a direct current through the armature and field in series, back to the outer ring and so returning to the source of the alternating current. This is spoken of by Leblanc as one solution of alternating current motors. It is not an alternating current motor in the strict sense of the word, because the alternating current is commuted before it is put into the machine. It is open to the same objection, of course, that the alternating current is broken at the point where it passes zero value, and the same remark applies to the field.

MR. W. FORMAN COLLINS:—When you break the circuit there, the field will lose its magnetism. Will not the armature act as a short circuit across the field.

LIEUTENANT PATTEN:—If the machine is in synchronism the current at this point is near zero, and the short circuit is then of little consequence.

MR. COLLINS:—It would induce very heavy sparking, would it not?

LIEUTENANT PATTEN:—It would if it were not for the isolated segments, on which the brushes then bear, and which offer a path for the current and so prevent its rupture.

MR. COLLINS:—Provided the field maintains some little magnetism.

LIEUTENANT PATTEN:—Yes; if it gives it up entirely; of course the reactionary effect would produce sparking.

MR. DUGALD C. JACKSON:—I should like to ask if all these schemes are not beating around the bush to get a continuous current motor, and if the size of the machine when put on practical circuits is not prohibitive, and that consequently we cannot with any of these devices get an alternating current motor that will do the work on practical circuits economically.

LIEUTENANT PATTEN:—If we accept the gentleman's remarks as conclusive that would settle the matter. I shall have to refer you to future generations for your answer.

MR. CHARLES J. REED:—I would like to ask one more question in regard to the action of these waves. As the potential varies from maximum to zero, will not the iron completely lose its magnetism each time as the potential falls to zero. I confess I am not posted on the rate of demagnetization of iron, but I am informed that in an ordinary converter the iron will actually become demagnetized something like twenty thousand times a minute. I would like to get some information on that. If that is so, and you use a current having a less number of reversals than that, would not the magnetism actually become zero between each of those successive impulses or waves?

LIEUTENANT PATTEN:—I would suggest that you call upon others to answer these question of general information. I would simply say in reply, that so far as my experience is concerned I have seen magnets that change their magnetism as slowly as fifteen times a second and retain enough to act as small dynamos; that is very slow as compared with 133 reversals which are used in this country, and 50 on the other side. But there undoubtedly is an approach to zero in the magnetic field, and there is at the same time a period of zero current in the armature. You can have an iron field that will not give up its magnetism in the 133d part of a second, and you can have one that will give it up in much less time, and you can have one that will retain it one-fifteenth of a second.

MR. REED:—Would not your laminated field be an objection in that it would tend to have the magnetism actually become zero at each reversal?

MR. MAILLOUX:—I think we can throw some light on this

point. I do not think that the magnetism would necessarily come to zero, for the reason that we are not dealing with a simple magnetic circuit. If we were dealing with a simple magnetic circuit in which there is no reaction against the lines of force in collapsing then you would doubtless get a very quick collapse of the magnetism, and possibly absolute zero of magnetism in the interval between the two pulsations. You might explain this by taking an ordinary magnetic circuit—a ring for instance—with a magnetizing coil, the ring consisting of very finely divided wire. Now, if there is no reaction (Foucault currents, etc.) against the flow of lines of force; if we assume the ring to be fully magnetized and the magnetism suddenly released, and if we even eliminate the self-induction of the magnetizing coil itself, then we will readily see that the magnetism will fall almost instantly. There are experiments which go to show that the fall of magnetism would take place in an inconceivably small space of time under such circumstances. But if we interpose in the path of the lines of force as they move, while rising or falling, a closed circuit or some other form that would tend to produce reaction, then we get what we call "Lenz effects," and in that case we cannot get such a rapid rise and fall. Now, in this machine the armature itself, the core and conductors are in the magnetic circuit; they form a part of it. Consequently at the time the magnetism is falling or rising there would have to be considered the reaction due to the conductors wound around the magnetic field itself, and also the conductors wound around the armature, and the currents induced in these conductors by either the rise or fall would necessarily tend to retard both the magnetizing and the demagnetizing process, and I should think that it would be possible to so regulate the self-induction of the different portions of the circuit as to control that. I at first thought that the demagnetization would take place very rapidly. I still believe that there will be a great fluctuation, but it would probably come considerably short of absolute zero. There would be a certain amount of residual magnetism during the intervals between the current waves.

DR. GARRATT:—On the general principle that sometimes "fools rush in where angels fear to tread," I would say that I confess that it does not seem to me that this question of the fall of magnetism of the field would be such a very serious one, although in this case I am speaking not at all from experience,

never having wound a machine of that character. But if I understood the gentleman correctly, the only reason why he laminates his field is to prevent undue heating at the starting of the machine. We have spoken of lamination as though it were a fixed thing. It may mean breaking up the core into two or three pieces or into a million. I suppose that it would be simply necessary to so proportion the laminations of the field that its magnetization would not fall unduly and so that in starting the machine the field magnets would not get unduly heated. It seems to me that it could be got at empirically in the natural process of building these machines of various sizes, and that it cannot be got at by pure inductive reasoning.

MR. E. T. BIRDSALL:—I think one point has been overlooked and that is, the action of different sizes of the machine. In small machines, we know that in breaking the magnetic circuit, the magnet loses its power very quickly. In large machines of twenty or thirty horse-power, it is known that magnets will not lose their magnetism for from two to three seconds, where the cores have a large amount of iron in them. In that case we might arrive at a mean degree of lamination, which would not produce too much heating. We might arrive at a size which would be a mean size of machine and which would give the best effect. It also struck me in regard to the magnetism falling, that possibly, although I have not thought it out, it does not matter so much whether the magnetism does fall, because everything else is zero at the same time the magnetism is zero.

THE CHAIRMAN:—There is one gentleman with us this evening who has had considerable experience in the manufacture of converters and also in their use, who, I think, could enlighten us on two or three of the points which have just been raised. I refer to Mr. Gutmann, I think he might favor us with one or two practical remarks on the subject.

MR. LUDWIG GUTMANN:—I think the motor just described is a very ingenious one, but we cannot discuss the motor itself as it stands alone. We have, of course, to consider it in connection with the circuit, because we want to transmit power. Synchronous motors generally can not be thoroughly successful because they will not answer all purposes. The same speed is not required in all cases. This motor, of course, is a step forward, because it can be so arranged as to permit the introduction of motors of different speeds on the same circuit. Nevertheless the motor is of the

constant speed type, while in practice a variable speed is often desirable. I see one serious objection to the motor, and that is, that it has the high potential current in the motor armature itself, and in case of any trouble arising, the consumer who has to handle it is immediately exposed to the danger of the medium or high-tension current in the main wires. That is the most serious trouble that I find with it. Otherwise I believe it would answer many purposes, because I think the motor will do its work well. It appears the motor would not start from a state of rest with any load on it and it would need a loose pulley so as to get up to synchronism before the load could be thrown on. This of course, would be a weakness, but not fatal; but I do think it serious that the machine requires a high potential. I do not think that this motor can be worked with low tension currents, because, especially to produce three or four horse-power, or more, the self-induction in those coils in connection with the mass of iron is great. If such a motor should be placed on an ordinary alternating current having about 1,000 or 1,500 volts, and we should always have to send practical and experienced men to repair the brushes, etc., because they are exposed to the 1,000 volt currents, and on this ground I do not think that it would be a solution of the problem, although a decided step in that direction.

LIEUTENANT PATTEN:—With reference to the high potential of the machine, of course in the general description I have given I have represented any source of alternating current of high or low potential, and so no special reference is made to its use as a high potential machine, on the direct mains from the station. The source of alternating current is presumably one suited to the conditions. With reference to the further difficulty mentioned, accidents will happen with any kind of machine, either direct or alternating, while the other forms of motor have some advantage in having ring contacts and sliding brushes that require no attention. The disadvantages that are introduced by bringing in the use of brushes are incident as well to the ordinary forms of motors. We are not so familiar with the kind that have no commutators that we have got used to their ease and simplicity of working. The second set of brushes are not, as I said before, brushes in the ordinary sense, and do not require adjustment and care. If a high potential machine is used, of course the ordinary precautions will have to be taken. It is not quite within the province of the alternating current motor to make the alternating current safe for everybody who uses it.

MR. GUTMANN:—I wish to point out that alternating current motors have this drawback, that the coils surrounding the iron core need a certain pressure to make any current flow through those coils—to get any power out of the motor we have to force the current through. Now, to produce five or ten horse power we need a certain number of ampere turns in the field. To have this certain number of ampere turns we must have a considerably higher pressure than might be supposed. We must have an armature to perform the work and to obtain the torque. Consequently I think it is impossible to realize a large amount of power without using medium or high tension currents for alternating current motors. Another point is, that we have to consider that alternating current motors will not always be placed in the hands of scientists, but will have to be used by inexperienced men, consequently I think this is a weakness in the motor if we have loose or sliding connections in a high potential circuit. I should prefer to have a motor, for instance, like Prof. Thomson's, in which the high tension current is fixed—no rubbing contact, and Mr. Tesla has shown us a motor without any commutator or brushes, and I believe there are many electricians hard at work to get something similar without a commutator, which is far preferable, but we will have to wait some time before we shall get that; and Thomson, for instance, has given us a motor in which the field alone is in the high tension circuit. This is the main drawback that I find to this motor. If we had no rubbing contact in these motors it would be a great advantage. As it stands, the armature is in series, or is in connection with the field, and consequently we have an increased self-induction, and we need a greater power and greater tension for this class of motor than we would if we had only to energize one of the two parts, either the armature or the field with the current, and that is the reason I said that there is a serious difficulty in introducing it into ordinary use.

THE CHAIRMAN:—If there is any gentleman here who is not a member, but who wishes to speak, we should be glad to hear from him. I noticed in the course of discussion that the criticisms so far on this motor have come from those who are partial to the alternating current motor, and may be said to be working in that field. But it seems to me that there are one or two criticisms or objections to be advanced from the continuous current side of the house, and those objections have been hinted

at by one gentleman on my left. With regard to the shape and size and weight of the alternating current motor as compared with others, it seems to me that there are one or two material and pertinent points to be dealt with. Dr. Wheeler perhaps might touch on that. We should also be very glad to hear from Mr. Blake.

DR. WHEELER:—You are very kind, but I have not heard all of the paper and I am not prepared to speak on it.

THE CHAIRMAN:—Haven't you read it?

DR. WHEELER:—I read it hastily. (Laughter.)

THE CHAIRMAN:—There being no other speaker, we should be glad to hear from Lieutenant Patten in reply and in conclusion, though I think his replies have already been numerous and in most cases almost conclusive.

LIEUTENANT PATTEN:—I think the alternating current motor might be left for the present. As to making a rival to the direct current motor, no attempt is made in that direction. The object is not to make a machine which has less weight and more efficiency at the outset than one that has been improved by the ablest talent of the world for the last five or six years. The question is, whether or not we can make an alternating current motor at all. If we could, the question might be put, what are you going to do with your current ten miles from here if you cannot get an alternating current motor? I think if the efficiency of such a machine drops to sixty per cent. it would not be a vital question in the problem with reference to the great importance of the transmission of power to great distances.

THE CHAIRMAN:—I am sure it has been a great pleasure to all of us this evening to learn from Lieutenant Patten how great and how rapid has been the improvement in the direction of giving us a practical and useful alternating current motor.

I now have much pleasure in announcing that for our October meeting we shall have a paper by Mr. Thomas D. Lockwood, a member of our Board of Managers, who has recently returned from a prolonged trip through Europe, and has made a great many observations on electrical development there, and who proposes to lay before us the pith of his notes on the subject. The paper will be read on October the 15th.

Adjourned.

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- The Efficiency of Methods of Artificial Illumination.** (Ill.) Ed. L. Nichols. *Am. Inst. Elec. Engrs. Lond. Elec. Rev.*, April 12, p. 412; April 19, p. 440; *Lond. Elec. Engr.*, April 19, p. 315; May 3, p. 352; May 10, p. 375; May 31, p. 432; *West. Elec.*, April 6, p. 191; *N. Y. Elec. Engr.*, April, pp. 158-188.
- Economics of Planning and Constructing Electric Light and Power Stations.** Alex. P. Wright. (Cont'd from p. 574.) *Lond. Elec.*, April 5, p. 624; April 26, p. 712; *Md. Lt. & Ht.*, April 4, p. 425. (Corr.) April 25, p. 510.
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- Arc Lamps and their Mechanism.** (Ill.) S. P. Thompson. *Soc. Arts. Lond. Elec.*, April 5, p. 627; *Lond. Elec. Rev.*, April 12, p. 430; April 19, p. 458; *Lond. Elec. Engr.*, April 5, p. 276; *N. Y. Elec. Rev.*, April 13, p. 2; *N. Y. Elec. Engr.*, May, p. 216; *Sci. Am. Supp.*, April 20, p. 11,079; April 27, p. 11,104; May 4, 11,116.
- On the Efficiency of Lamp Sockets and Switches.** H. Hutchins. *Elec. World*, April 6, p. 204.
- Central Station Lighting.** Geo. Forbes. *Instn. Elec. Engrs. West. Elec.*, April 13, p. 204.
- Licensing Electric Light Employees.** *Lond. Eng.; N. Y. Elec. Rev.*, May 4, p. 9.
- New England Insurance Rating of Electric Lighting.** *N. Y. Elec. Rev.*, May 4, p. 10.
- The Electric Light in Portland, Oregon.** *N. Y. Elec. Rev.*, April 6, p. 9.

- Accumulator Installation in a Chicago Residence.** (Ill.) *West. Elec.*, May 18, p. 257.
- Edison Electric Light Company's Station at Philadelphia.** (Ill.) *West. Elec.*, May 25, p. 279.
- Electric Light Plant at the Massachusetts General Hospital.** (Ill.) *Elec. World*, May 11, p. 272; *N. Y. Elec. Rev.*, May 11, p. 9.
- The Fort Worth, Tex., Electric Light Station.** (Ill.) *Elec. World*, May 18, p. 281.
- Electric Light on Board the Yorktown.** (Ill.) *N. Y. Elec. Rev.*, April 6, p. 1.
- Bids for Lighting New York.** *N. Y. Elec. Rev.*, April 6, p. 9.
- Lighting at Danvers, Mass.** *Md. Lt. & Ht.*, May 30, p. 633.
- A Water Power Electric Light Station.** *Md. Lt. & Ht.*, May 9, p. 562. (Lewiston & Auburn Electric Light Company.)
- New Cincinnati Central Station.** *West. Elec.*, May 4, p. 237.
- Edison General Electric Company.** *West. Elec.*, May 25, p. 280; *Elec. World*, May 18, p. 286.
- Chicago City Electric Light Plant.** *West. Elec.*, May 25, p. 270.
- Centennial Electrical Notes in New York.** *Elec. World*, May 11, p. 274.
- Extensive Electric Lighting in St. Louis.** *Lond. Elec. Rev.*, April 5, p. 383.
- Edison Central Station at Milan.** (Ill.) *West. Elec.*, April 6, p. 188.
- The Brush Company of London.** *N. Y. Elec. Rev.*, April 6, p. 9.
- Electric Lighting in London.** *Indust.*, May 24, p. 494.
- Alternating Current Lighting in London.** (Ill.) *Elec. World*, May 4, p. 261.
- The Lighting of London.** (Ed.) *Lond. Elec.*, May 10, p. 11.
- Electric Lighting in London.** *Lond. Elec. Engr.*, May 24, p. 417; *West. Elec.*, May 11, p. 247.
- Lighting the Garrick Theatre.** *Lond. Elec. Rev.*, May 3, p. 306.
- Central Station Lighting in Glasgow.** *Lond. Elec. Engr.*, May 17, p. 392; *Indust.*, May 17, p. 471; May 24, p. 496.
- Electric Lighting at Havre.** *Lond. Elec. Rev.*, April 26, p. 468.
- Electric Lighting in the West (England).** *Lond. Elec. Rev.*, May 3, p. 516.
- Electric Lighting at the Melbourne Centennial Exhibition.** *Lond. Elec.*, May 10, p. 12; *Lond. Elec. Rev.*, May 10, p. 544.
- Central Station Lighting in Paris.** *Lond. Elec. Rev.*, May 17, p. 557.
- The Electric Light at the Paris Exhibition.** *Elec. World*, May 11, p. 270; *Lond. Elec.*, May 10, p. 5; *West. Elec.*, May 11, p. 248; *Sci. Am. Supp.*, May 25, p. 11,169; (Ill.) *Indust.*, April 19, p. 378; *N. Y. Elec. Engr.*, May, p. 238.

- Central Stations in France.** (Note.) *Lond. Elec. Rev.*, May 31, p. 627.
- Some Electric Lighting Central Stations in Europe, and their Lessons.** (Ill.) I. G. Forbes. *Instn. Elec. Engrs. Lond. Elec.*, April 19, p. 679; April 26, p. 716. (Corr.) (Ganz & Co.) *Lond. Elec. Rev.*, April 19, p. 463; *Science*, May 3, p. 337; *Elec. World*, May 4, p. 462.
- The Barmen Central Station.** (Ill.) *Lond. Elec. Rev.*, May 17, p. 561.
- The Central Station Distributing Mains at Barmen.** *Lond. Elec.*, May 17, p. 35.
- Electric Light in Germany.** (Note.) *Lond. Elec. Engr.*, April 5, p. 268.
- German Central Electric Lighting Stations.** *Lond. Elec.*; *Elec. World*, April 20, p. 229.
- The Berlin Electric Light Stations.** (Ill.) *Elec. World*, May 25, p. 298.
- Electric Light at the Mysore Palace.** (Note.) *Lond. Elec.*, April 26, p. 699.
- Electric Lighting for the City of Brussels.** *Elec. World*, April 27, p. 243.
- Electric Lighting in a Pit.** *Lond. Elec. Rev.*, May 10, p. 531. (Anzin, France.)
- Determination of Sizes for Inside Wiring on the Two-Wire System for Beginners.** C. E. Gifford. *Elec. World*, May 25, p. 299.
- Wiring the Colonnade Hotel, Philadelphia.** *Elec. World*, May 11, p. 274.
- Standard Rules for Wiring Buildings.** H. H. Humphrey. *Elec. World*, May 4, p. 260.
- The Wiring of Buildings for Electric Light.** (Ill.) J. D. F. Andrews. *Phil. Soc.*, Glasgow. *Lond. Elec.*, April 5, p. 619; *Lond. Elec. Rev.*, April 5, p. 384; *Lond. Elec. Engr.*, April 5, p. 269; *West. Elec.*, April 27, p. 228; *Sci. Am. Supp.*, May 25, p. 11,167.
- Calculation of the Size of Electric Light Conductors.** *Lond. Elec. Rev.*, May 24, p. 587.
- Standard Rules for Wiring Buildings.** C. H. Crockett. *Elec. World*, April 20, p. 228.
- Compound Winding Patents, King, Brown & Co. vs. Anglo-American Brush Electric Light Corporation, Limited.** *Lond. Elec. Rev.*, May 31, p. 631; *Lond. Elec.*, May 31, p. 91.
- Annulment of the Edison Lamp Patent in Canada.** *N. Y. Elec. Engr.*, April, p. 199.
- On the Security Against Disturbance of Ships' Compasses by Electric Lighting Appliances.** Sir W. Thomson. *Instn. of Elec. Engrs. Lond. Elec. Engr.*, May 31, p. 431; *Indust.*, May 31, p. 523; *Lond. Elec.*, May 31, p. 87.
- Specification of Conditions for Supplying the City of London with Electricity.** (Ill.) *Lond. Elec. Engr.*, April 19, p. 316.
- A Compact Plant for Railway Trains.** (Ill.) *N. Y. Elec. Rev.*, May 18, p. 8. (J. H. Bunnell & Co.)

DYNAMOS, SYSTEMS OF DISTRIBUTION, ETC.

- The New Edison Dynamo for Marine Work.** (Ill.) *Elec. World*, April 6, p. 201.
- The "Lahmeyer" Dynamo.** (Note.) *Lond. Elec. Engr.*, May 3, p. 347.
- Alternating Current Dynamos.** (Ill.) *Lond. Elec. Rev.*, May 17, p. 563.
- The Westminster Dynamo.** (Ill.) *Indust.*, April 26, p. 401; *Elec. World*, May 18, p. 284.
- The Silvertown Dynamo.** *Sci. Am. Supp.*, May 11, p. 11,133.
- Right and Left Hand Dynamos.** (Ill.) *West. Elec.*, April 13, p. 199.
- The Fritsche Wheel Dynamo.** (Ill.) *Elec. World*, April 6, p. 205; *N. Y. Elec. Rev.*, April 6, p. 2; *Lond. Elec.*, April 12, p. 655; (Corr.) *Indust.*, April 12, p. 350; *Sci. Am. Supp.*, May 4, p. 11,120.
- Smit's Arc Light Dynamo.** (Ill.) *Indust.*, May 17, p. 473.
- Increasing the Output of Transformers.** (Note.) *Lond. Elec. Engr.*, May 17, p. 388.
- Remarks on Frans Wilking's "Contributions to the History of Transformers."** A. Gelyi. *Lond. Elec. Rev.*, May 17, p. 556; May 24, p. 591.
- Uppenborn's History of the Transformer.** (Corr.) Rankin Kennedy. *Lond. Elec. Rev.*, May 10, p. 552.
- The Gans Alternator and Transformer.** (Ill.) *Indust.*, May 3, p. 425; May 10, p. 444; *Science*, May 10, p. 365.
- The Kapp Regulating Transformer.** (Ill.) *Lond. Elec. Engr.*, April 19, p. 310; *Indust.*, April 12, p. 353; *West. Elec.*, May 4, p. 234; *Lond. Elec. Rev.*, April 26, p. 471; *N. Y. Elec. Rev.*, May 4, p. 9; *Elec. World*, May 4, p. 256.
- A New Form of Self-Induction and Regulating Coil.** (Ill.) *Science*, April 5, p. 252.
- The Function of the Condenser in an Induction Coil.** J. A. Fleming. *Lond. Elec.*, May 31, p. 84.
- Prof. Elihu Thomson's New Method of Regulating Current or Potential in the Secondaries of Transformers.** (Ill.) *Elec. World*, April 13, p. 218; *Lond. Elec. Rev.*, April 26, p. 474; *Lond. Elec. Engr.*, April 26, p. 335.
- Mishaps with Dynamos.** (Corr.) Jos. Wills. *Elec. World*, April 27, p. 245.
- Tangent Function Multipliers to be Used with the Kapp Formulae in the Design of Dynamos and Motors.** Albion T. Snell. *Elec. World*, April 20, p. 234.
- A Synthetic Study of Dynamo Machines.** (Ill.) (Cont'd from p. 93.) *Lond. Elec. Rev.*, April 5, p. 380; April 19, p. 446; May 3, p. 502; May 24, p. 593.
- The Starting of the Dynamo Electric Current.** *Annalen der Physik und Chemie*, *N. Y. Elec. Rev.*, May 25, p. 2.

- In the Dynamo Room.** L. F. Lyne. *Elec. Pr.*, May, p. 122.
- Electrical Distribution in Brussels.** *Lond. Elec. Rev.*, April 5, p. 383.
- The Rival Alternating Current Distributing Systems in London.** *Indust.*; *N. Y. Elec. Engr.*, April, p. 176.
- Müller and Lahmeyer's Distributing System.** (Ill.) *Lond. Elec.*, April 26, p. 703.
- Transfer System of Electrical Distribution.** (Ill.) *West. Elec.*, April 13, p. 198.
- On the Distribution of Continuous Electric Currents by Means of Condensers.** (Ill.) S. Doubrava. *Lond. Elec.*, April 19, p. 676; *Elec. World*, May 18, p. 285.
- Gaulard and Gibbe Transformer Patent Case.** *Indust.*; *Elec. Pr.*, April, p. 94.
- On the Winding of Resistance Coils Intended to be Measured by Alternating Currents.** M. G. Chaperon. *Comptes Rendus*; *Lond. Elec. Rev.*, May 10, p. 530.
- Alternate Current Working.** (Ill.) W. M. Mortley. *Instn. Elec. Engrs.* *Lond. Elec. Rev.*, May 31, p. 634; *Lond. Elec. Engr.*, May 24, p. 420; May 31, p. 437; *Lond. Elec.*, May 24, p. 64; May 31, p. 94; *Indust.*, May 31, p. 521.
- The Ferranti Ten Thousand Volt Conductor.** *N. Y. Elec. Rev.*, May 4, p. 1.
- High vs. Low Tension Currents.** *Lond. Elec. Rev.*, May 31, p. 617.
- Cutter Adjustable Brush Trimmer.** (Ill.) *West. Elec.*, April 6, p. 189.
- The Kester Dynamos and Motors.** (Ill.) *N. Y. Elec. Rev.*, May 11, p. 8.

ELECTRIC MOTORS.

- Alternate Current Motors.** *Lond. Elec. Rev.*; *Elec. Pr.*, May, p. 123.
- The Tesla Motor.** (Ill.) *Sci. Am. Supp.*, April 6, p. 11,053.
- Mr. Nikola Tesla on Alternating Current Motors.** (Corr.) Nikola Tesla. *Elec. World*, May 25, p. 298.
- Gans & Co's Alternate Current Motor.** (Ill.) *West. Elec.*, May 25, p. 269; *Elec. World*, May 25, p. 297; (Corr.) *Lond. Elec.*, May 10, pp. 16-18; *Elec. World*, May 4, p. 258; *Lond. Elec. Engr.*, May 17, p. 393.
- Ten Horse Power Constant Current Motor for Ampere Circuits.** *N. Y. Elec. Rev.*, April 6, p. 9.
- A New Motor in Washington, D. C.** *Washington Press*; *N. Y. Elec. Rev.*, April 6, p. 8. (River & Rail Elec. Co.)
- Denison Motors and Dynamos.** (Ill.) *Elec. Pr.*, May, p. 115.
- The Edgerton Electric Motor.** H. N. Edgerton. *Elec. Pr.*, May, p. 111.
- Waterproof Motor.** (Note.) *Lond. Elec. Engr.*, May 24, p. 407. (Sprague.)

- An Amphibious Motor.** (Corr.) Merle J. Wightman. *Elec. World*, April 13, p. 220. (Thomson-Houston waterproof motor.)
- The Connecticut Motor Company.** (Ill.) *Elec. Pr.*, April, p. 95.
- Electrical Transmission of Power.** *Elec. Pr.*, April, p. 84. (Ile au Heron.)
- The Electric Traveling Crane at the Paris Exposition.** (Ill.) *Elec. World*, May 4, p. 261.
- Operating the Bridgeport, Conn., Drawbridge by Electric Motor.** (Ill.) *Elec. World*, April 20, p. 231; *Md. Lt. & Ht.*, April 18, p. 484; *Science*, April 26, p. 312; *Elec. Pr.*, May, p. 114; *N. Y. Elec. Rev.*, April 20, p. 3; *West. Elec.*, April 20, p. 215.
- Electric Coal Digger.** (Ill.) *Science*, April 5, p. 250. (Sperry's.) *Elec. Pr.*, May, p. 123.
- Applications of Electromotive Power to Mill Work.** W. S. Kelley. *Elec. Pr.*, May, pp. 117-121.
- The Electric Motor in Telephonic Service.** C. M. Catlin. *Elec. Pr.*, May, p. 111.
- Printing by Electricity.** (Note.) *Lond. Elec. Engr.*, April 5, p. 268.
- "C. & C." Installations and Apparatus.** (N.) *N. Y. Elec. Rev.*, May 25, p. 8.
- A Unique Electric Power Station.** *Science*, April 5, p. 251. (Scranton, Pa.) *Elec. Pr.*, April, p. 85.
- Electric Power Transmission at Virginia City, Nev.** *Territorial Enterprise*; *Elec. Pr.*, April, p. 100; *N. Y. Elec. Rev.*, May 25, p. 1; *West. Elec.*, May 25, p. 271; *Elec. World*, May 25, p. 293.
- The Kearney (Neb.) Power Station.** (Ill.) *Elec. World*, April 6, p. 205.
- Electrical Transmission of Power.** *Lond. Elec. Rev.*, May 10, p. 526. Wattenser Paper Works, Austria, Hungary.
- Electric Power from the Rhine.** (Corr.) *Lond. Elec. Engr.*, May 17, p. 387.
- A Power Station at Rheinfelden.** *Lond. Elec.*, April 19, p. 674; *Elec. World*, May 11, p. 268.
- A New Device.** *Md. Lt. & Ht.*, May 23, p. 609. (Lieut. Fiske's Shot Hoist.)
- Calculations for Long Distance Electric Power Transmission.** Lemuel W. Serrell, Jr., *Elec. World*, May 25, p. 292.
- The Electric Motor. How it Moves.** (Ill.) Frank L. Perry. *West. Elec.*, May 18, p. 260.
- The Transmission of Power by Electricity.** Frank J. Sprague. *Fla. Inst. Lond. Elec. Engr.*, April 5, p. 272; April 12, p. 292; April 19, p. 312; May 3, p. 358; *Lond. Elec. Rev.*, May 10, p. 527.
- Alternating Current Motors.** (Ill. Corr.) Dr. Kittler. *Lond. Elec. Rev.*, May 17, p. 580.

Alternating Current Motors. *Lond. Elec. Rev.*, April 26, p. 476. (Ganz & Co.)

On the Speed Regulation of a Motor in the Electrical Transmission of Power. M. Marcel Deprez. *Comptes Rendus; Lond. Elec. Rev.*, April 26, p. 468.

Note on the Efficiency of Small Electro-Motors. H. E. H. Clifford. *Lond. Elec. Rev.*, April 12, p. 408.

Units of Electric Power. (Corr.) J. W. —. C. O. Mailloux. *Elec. Pr.*, April, p. 99.

Constant Current and Constant Potential Motors. C. O. Mailloux. *Power, Steam; Elec. Pr.*, April, p. 92.

Electric Power for Small Industries. G. K. Holmes. *Elec. Pr.*, April, p. 81.

Something Electricity is Doing. C. Barnard. *Century; Elec. Pr.*, April, p. 88.

Canal-Boat Propulsion. H. C. Vogt. *Brit. Assn. Science*, April 12, p. 278.

An Electric Drill. *Md. Lt. & Ht.*, April 25, p. 509. (I. E. Story.)

The Hawkeye Electric Company. *West. Elec.*, May 4, p. 240.

Davis Motor in a Press Room. (Ill.) *West. Elec.*, April 20, p. 211.

Lamp Out-Out for Motor Circuits. (Ill.) *West. Elec.*, April 20, p. 211.

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The Daft "Double Trolley" Road at Cincinnati, O. (Ill.) *Elec. World*, May 25, p. 295; *West. Elec.*, May 25, p. 275; *Science*, May 24, p. 391.

Largest Electric Railway System in the World, Topeka, Kana. *Md. Lt. & Ht.*, April 11, p. 461; May 23, p. 610; *Science*, April 26, p. 319; *N. Y. Elec. Rev.*, May 4, p. 2; May 25, p. 10; *West. Elec.*, May 25, p. 277; *Elec. World*, May 25, p. 296.

The Electric Railway in St. Joseph, Mo. (Ill.) *Science*, April 5, p. 252.

The Thomson-Houston System on West End Street Railway, Boston. (Ill.) *Elec. World*, April 6, p. 204; May 11, p. 269; *Md. Lt. & Ht.*, April 4, p. 427; May 9, p. 557; *N. Y. Elec. Engr.*, May, p. 206.

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- A New Daft Electric Street Car.** (Ill.) *Elec. World*, April 20, p. 229.
- New Bentley-Knight Double Motor Truck.** (Ill.) *Elec. World*, May 4, p. 258; *West. Elecn.*, May 4, p. 235.
- The Bentley-Knight Tram.** (Ill.) *Lond. Elec. Engr.*, April 12, p. 295.
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- Thomson-Houston Electric Roads.** *Elec. World*, May 4, p. 262.
- Carbon Brush for Railway Motors.** *Elec. Pr.*, May, p. 125. (Thomson-Houston.)
- The Thomson-Houston Electric Railway Snow Broom.** (Ill.) *Elec. World*, April 13, p. 220; *Elec. Pr.*, May, p. 132; *Science*, April 12, p. 273; *N. Y. Elec. Rev.*, April 13, p. 3; *Md. Lt. & Ht.*, April 11, p. 462.
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- The Van Depoele System of Electric Railway.** (Ill.) *Lond. Elecn.*, April 12, p. 660.
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- Electric Locomotives.** *Elec. Pr.*, April, pp. 96, 102. (Daft, Ninth Avenue.)
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- Recent Additions to the Sprague Electric Roads.** *Lond. Elec. Rev.*, April 12, p. 420. (St. Joseph, Harrisburg & Wilmington.) April 19, pp. 455-457. (Ill.) Brockton, Mass., Reading. *Elec. World*, April 6, p. 208.
- Electric Locomotive for Mines.** *Elec. Pr.*, April, p. 86.
- The Carstairs (Scotland) Electric Railway.** *Lond. Elec. Engr.*, May 10, p. 370; *Lond. Elecn.*, May 10, p. 7; *Lond. Elec. Rev.*, May 10, p. 546.
- Electric Locomotive on the Birmingham Tramways.** *Indust. Elec. Pr.*, April, p. 85.
- The Series Electric Railway at Gravesend, England.** (Ill.) *Elec. World*, April 13, p. 219; *Science*, April 5, p. 259.
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- Secondary Battery Car in Detroit.** *Elec. Pr.*, April, p. 101; *Science*, April 19, p. 297.

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- The "Edco" Storage Car in Philadelphia.** *Ledger; Elec. World*, April 20, p. 234; May 11, p. 271; *N. Y. Elec. Rev.*, April 27, p. 2; *West. Elecn.*, May 4, p. 237; *West. Elecn.*, April 20, p. 213.
- Electric Street Railways.** Fred. H. Whipple. *West. Elecn.*, May 4, p. 240.
- Producing, Transmitting and Applying Electricity for Street Railway Purposes.** Fred. H. Whipple. *West. Elecn.*, May 25, p. 273.
- Electric Traction.** *Zeitschrift für Elek.; Elec. Pr.*, May, p. 136.
- Increased Traction Due to Electric Currents.** (Corr.) Elias E. Ries. *Elec. Pr.*, May, p. 134.
- The Acme of Rapid Transit.** *Elec. Pr.*, May, p. 125.
- Electric Railways.** Eugene Griffin. *Bost. Soc. Arts. Md. Lt. & Ht.*, May 2, p. 534; May 9, p. 556. *Merchants Club. Md. Lt. & Ht.*, May 16, p. 588; *N. Y. Elec. Rev.*, May 11, p. 2.
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- Maximum Gradients on Electric Railways.** *Eng. News; Elec. Pr.*, April, p. 83.
- The Electric Locomotive.** Oberlin Smith. *Elec. Pr.*, April, p. 82.
- Advantages of Electric Railways.** J. C. Henry. *Cal. Elec. Soc. Elec. Pr.*, April, p. 87.
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- Peckham Elastic Motor Wheel.** (Ill.) *West. Elecn.*, May 11, p. 249.
- On the Growth of City Traffic in New York and London.** A. Reckenzaun. *Lond. Elec. Rev.*, May 24, p. 588.

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- Re-Series Line at Northfleet.** (Corr.) E. Manville. *Lond. Elec. Rev.*, April 12, p. 436. Wilfred L. Spence. April 19, p. 464.
- An Engine-Dynamo Accumulator Car.** *Lond. Elec. Engr.*, April 12, p. 287.
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- The Portelectric System of Transportation.** (Ill.) *Elec. World*, May 4, p. 257.
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- Mance's Battery Resistance Test.** (Corr.) R. L. Hippisley. *Lond. Elec.*, April 5, p. 634.
- On Batteries.** A. E. Dolbear. *Med. Lt. & Ht.*, May 16, p. 587.
- The Arrest of Growth of Cancer by Powerful Interrupted Voltaic Currents.** J. I. Parsons. *Lond. Elec. Rev.*, May 3, p. 498.
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- London Chamber of Commerce.** *Lond. Elec. Engr.*, May 17, p. 400.
- Another Project. The Engineers' Institute.** *Lond. Elec. Rev.*, May 3, p. 500.
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ENGINEERING.	<i>Eng.</i>	London, 35-36 Bedford St. W. C.; weekly. £1.16.
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THE ELECTRICIAN.	<i>Lond. Elec.</i>	London, 1 Salisbury Court, E. C.; weekly. £1.2.
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THE ELECTRICAL ENGINEER.	<i>N. Y. Elec. Engr.</i>	New York, 11 Wall Street; monthly, \$3.
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